METEOROLOGY.

EDINBURGH: PRINTED BY JOHN GREIG.

T

INTRODUCTION

TO

METEOROLOGY.

BY

DAVID PURDIE THOMSON, M.D.

GRAD. UNIV. EDIN.

LICENT. ROY. COLL. OF SURGEONS, EDIN.

"Homo, naturæ minister et interpres, tantum facit et intelligit, quantum de naturæ ordine se vel mente observaverit: nec amplius scit nec potest."

LORD BACON,—*Nov. Organum*, Aph. i.

WILLIAM BLACKWOOD AND SONS,
EDINBURGH AND LONDON.
MDCCCXLIX.

TO

THE RIGHT HONOURABLE THE

VISCOUNTESS COMBERMERE,

THESE PAGES ARE,

BY PERMISSION,

MOST RESPECTFULLY INSCRIBED

BY

THE AUTHOR.

CONTENTS.

INTRODUCTION.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

APPENDIX.

METEOROLOGICAL INSTRUMENTS.

INTRODUCTION.

Before entering upon the subject of this treatise, a brief sketch of the surface of our globe and of its motions through space, we deem an important and fit introduction. To Physical Geography belongs the full examination of the one,—to Astronomy, the investigation of the other.

From the time when the earth was first accounted the centre of the universe, till now that it has assumed a very subordinate place among the heavenly bodies, nations have passed away, empires have risen and kingdoms fallen, but the globe remains, unchanged in its magnitude, revolving in endless curves obedient to the fiat of Him who in the beginning created the heaven and the earth.

The earth is one of the numerous bodies which revolve round the sun, and though to us, its occupants, it may seem the most important, neither in its magnitude nor in its attendants is it worthy of this distinction. It is distant from that glorious orb 95,000,000 of miles;[1] upon the 1st of January the distance amounts to 93,410,000 miles, and on the 1st of July to 96,595,000,—these being the extremes.

The form of the earth is spherical, with a slight flattening

[1] The mean of the extreme distances is 95,002,500 miles, but that of the twelve monthly distances is 95,023,750 miles.

at the poles,—technically, an *oblate spheroid,*—the relative diameters being in the proportion of 300 to 299, or as 2 to 1.99 : the mean diameter amounts to 7,913.45 miles, and the mean circumference to 24,885. This determination of the figure of our globe has been the result of patient and laborious inquiries, made in all parts of the earth, with instruments of the most delicate construction.

The surface of the earth is diversified by land and water, hill and valley. This variety demands as well from the political economist as from the lover of nature, unbounded praise and admiration,—in wisdom hast Thou created them. Upon inspecting a terrestrial globe, two impressions are forcibly conveyed, viz., the peculiar conformation of the land, and its small proportion to the ocean. By far the larger portion of the former is observed to lie north of the equator, and by much the greater part of the latter is met with south of that imaginary line. If, instead of dividing the globe into geographical hemispheres, we make London and its antipodal point near New Zealand, the centres of two great circles meeting at a common equator, the unequal distribution of land and water will be still more remarkable.[1] Suppose the eye looking down upon these hemispheres from points in space far above our globe, the aspect of the two will be very dissimilar: while the one will have a very large proportion of dry land, and a considerable surface of ocean, the other may not inaptly be called a world of waters,—the southern part of South America will be seen, and the whole of Polynesia with the antarctic land, but by far the largest portion of this hemisphere will be found occupied by water. Again, divide the earth *longitudinally*, by a line passing through Teneriffe, and the half of the globe to the American side of that line will be found to contain less land than that on the Asiatic aspect.

[1] See Sir Charles Lyell's Map—Princip. of Geol. pl. i. vol. i.

The computed ratio of the dry land to water, is as 1 to 2.75 ; or, dividing the entire surface of the globe into 10,000 equal parts, 2666 of these are occupied by the one, and 7334 by the other.

The dry land is very varied by its inequalities. We find upon its surface solitary hills and mountain-ranges, with varying contour, declivities, and heights ; ravines, dells, and valleys, and these principal, lateral, and subordinate, according to their relations to the mountain-chain in its several parts. Besides these, we meet with table-lands, steppes, deserts, llanos, pampas, savannas, prairies, and forests.

Having thus cursorily noticed the peculiarities of the earth's surface, we pass to a hasty examination of the motions of our globe upon its axis and round the sun. By the one we have the division of time into days and nights, by the other into years. It is important that we should consider more particularly the latter motion, for to it, together with the inclination of the earth's orbit, do we enjoy the regularity and diversity of the seasons.

If we draw a ribbon round a terrestrial globe, covering those parts over which the sun appears in the zenith, we isolate from the rest of the earth's surface a zone, the breadth of which is 47°, including within it the *equator.* If we now connect together by a thread those places upon which that luminary is daily vertical at noon, we mark out the sun's apparent path, which has been termed the *ecliptic :* this line inclines 23°.5 to the equator, and cuts it in two points upon opposite sides of the globe. This band has been termed the *torrid zone,* from its constant exposure to an ardent sun : beyond it and on either side lie the *temperate zones,* the breadth of each of which is 43° ; and farther north and south we find the *frigid zones,* with the poles in their centre distant from the temperate zones 23°.5. Although this is an artificial

division of our globe, it is nevertheless natural, for as the torrid zone is represented by a vertical sun, so the frigid zones are characterised by the partial absence of that luminary, while the temperate zones enjoy the happy medium of mean temperatures,—there, the incident beams fall at angles varying according to the season, and the sun never ceases to enliven the day.

In ordinary *parlance*, the sun crosses the equator on the 21st of March and the 23d of September, upon which days he rises and sets due east and west. Between these days during the summer and winter seasons, the sun appears in the morning and sinks to his bourne in the evening, to the north and south of these points respectively. He obtains his highest northern declination on the 21st of June, and gains the greatest southern latitude on the 22d of December, on which occasion his position is 23° 27′ from the equator. Upon the former of these days (the *longest* day), the interval between sunrise and sunset extends to 16 hours 32 minutes; on the latter (the *shortest* day) it amounts to 7 hours 47 minutes: upon the one, he advances to a meridian altitude of about 62°; on the other he decreases to that of 12°. Although the sun moves over the same number of degrees in nearly the same periods, his vertical rays do not beam for an equal length of time upon every portion of the torrid zone. This arises from the inclination of the ecliptic. Dividing this great band of our earth's surface into three equal parts, by lines running parallel to the equator, each of these will have a breadth of 15° 40′, and the middle one will have its limits in north and south latitude 7° 50′; consequently, when the sun has a declination less than 7° 50′, it will be vertical over this central band, but when it exceeds that number, it will be either north or south of it, according to the period of the year. From these premises we find that the sun is vertical within that internal

band twice in the course of a year, viz., from the 1st of March to the 10th of April, and from the 3d of September to the 13th of October, and once in each of the others, viz., from the 10th of April to the 3d of September in the northern, and from the 13th October to the 1st of March in the southern. The sun thus shines vertically upon the central third of the torrid zone during two periods of 41 days, distant from each other 145 and 138 days; while he broods over northern and southern divisions for nearly 21 and 20 weeks together.

There is still another motion of our globe which it would be improper to omit, although we are yet unable to say whether it exercises any influence upon Meteorology. We refer to the motion of our sun and all its planets round a focus as yet invisible: this we deem the most brilliant discovery in Sidereal Astronomy. For it we are indebted to M. Peters of Pulkova, who, from the observations of MM. Otto Struve, and Argelander, has determined some of its elements. This motion amounts to 154,185,000 miles yearly, or is at the rate of 57 miles every second; and the point to which we are hastening is in the constellation Hercules. This point was in 1840 in Right Ascension 259° 35′.1 and N. Declination 34° 33′.6, with a probable error of 2° 57′.5 in the former, and 3° 24′.5 in the latter. "To that now dark and mysterious centre," says the learned and profound philosopher Sir David Brewster,[1] "from which no ray, however feeble, shines, we may in another age point our telescopes—detecting, perchance, the great luminary which controls our system, and bounds its path—into that vast orbit which man during the whole cycle of his race may never be allowed to round. If the buried relics of primeval life have taught us how brief has been our

[1] North Brit. Rev. Feb. 1848, No. xvi. p. 533,—Herschel's Astron. Observa. and M. F. W. G. Struve's Etudes d' Astron. Stellaire.

tenure of this terrestrial paradise compared with its occupancy by the brutes that perish, the sidereal truths which we have been expounding, impress upon us the no less humbling lesson, that from the birth of man to the extinction of his race, the system to which he belongs will have described but an infinitesimal arc of that immeasurable circle in which it is destined to revolve.

"In the contemplation of the infinite in number and in magnitude, the mind ever fails us. We stand appalled before the mighty spectre of boundless space, and faltering reason sinks under the load of its bursting conceptions. But placed, as we are, on the great locomotive of our system, destined surely to complete at least one round of its etherial course, and learning that we can make no apparent advance on our sidereal journey, we pant with new ardour for that distant bourne which we constantly approach without the possibility of reaching it. In feeling this disappointment, and patiently bearing it, let us endeavour to realize the great truth from which it flows. It cannot occupy our mind without exalting and improving it. It cannot take its place among our acquirements without hallowing and ennobling them. Though now but a truth to be received, it may yet become a principle of action, and though now veiled by a cloud, it may yet be a lamp to our feet and a light to our ways. Whom God made after His own image, he will not retain in perpetual darkness. What man's reason has made known, man will be permitted to see and understand. 'He that bindeth the sweet influences of Pleiades, and looseth the bands of Orion, and quieteth Arcturus with his sons,' will in his own time 'discover deep things out of darkness' and 'reveal the ordinances of heaven.'"

Of the influence exerted upon Meteorology by the physical conformation of our globe and the motions thus briefly described, we would observe, that, as in the sequel, reference will

occasionally be made to the former, here we will confine our introductory remarks to the latter. The influence of the diurnal motion need not detain us:—by it we have the agreeable transition from darkness to light, and from the cool of night to the warmth of day. We have thus diurnal extremes of temperature, and, through the power which caloric possesses of suspending aqueous vapour, changes in the humidity of the atmosphere; we have also mutations in the density of the aërial fluid surrounding us, and vicissitudes in its electric tension.

The influence of the annual revolution of our earth would be negative, were it not the inclination of the ecliptic, which produces important effects in the distribution of caloric, and leads to the vicissitudes of seasons. It is in consequence of this that we observe such changes in the sun's altitude at noon, and in the hours of his rising and setting,—changes which are attended by an alternate increase and diminution of heat in the course of a revolution. But it is not when the sun has acquired his greatest northern declination that the maximum annual temperature is gained; this epoch occurs some time after the summer solstice, when the caloric received from the sun equals that which is lost by terrestrial causes;—previous to this, the solar heat has been in excess, and consequently the temperature has been rising. We meet with a parallel phenomenon in the hour of maximum diurnal temperature, which, unless modified by a peculiarity in the physical features of the locality, is invariably found to occur *after* the sun has culminated. When the sun declines and passes into southern latitudes, the consumption of caloric by the earth exceeds the amount supplied by that luminary, consequently the temperature falls, and, for reasons similar to those which retard the epoch of maximum temperature, so

that of minimum temperature occurs some days after the winter solstice.

We have dwelt upon the motion of the sun over the three equal divisions of the torrid zone, with the view of explaining why the greatest terrestrial temperature is not met with upon the equator, and to direct attention to the cause of the frequent storms which attend his passage across the central portion of that zone.

Such are the influences upon Meteorology arising from Astronomical relations. We have considered them briefly, but they open a rich field for reflection. Of the atmospheric influences which may result from the motion of our planet in space, we are still in ignorance, and the author is unwilling to conjecture.

METEOROLOGY.

CHAPTER I.

1. Meteorology defined. 2. History; Superstitions of the Ancients. 3. General considerations. 4. Rise of Pneumatic Chemistry. 5. Composition of the Atmosphere,—Oxygen and Nitrogen. 6. Carbonic Acid. 7. Adventitious products. 8. Ratio of Oxygen and Nitrogen constant. 9. Distribution of these Gases. 10. Their physical properties,—Oxygen, Nitrogen. 11. Carbonic Acid Gas. 12. Nitrogen found *free* in South America. 13. Carbonic Acid *free* in several localities. 14. Grotto del Cane. 15. Valley of Death in Java. 16. Considerations on the quantitative composition of the atmosphere. 17. Speculation of Brongniart. 18. Source of the renewal of Oxygen consumed.

"O Nature! how in every charm supreme!
Whose votaries feast on raptures ever new;
O for the voice and fire of Seraphim,
To sing thy glories with devotion due!"

BEATTIE.

1. METEOROLOGY is the science which acquaints us with the various phenomena of the atmosphere. It leads us to inquire into its properties and relations.

2. On entering upon the study of any science, it is usual to trace its history; but upon that of Meteorology, little information is cast by the records of antiquity. The observations of the ancients were directed chiefly to changes in the weather; and by personal assiduity, they were enabled to prognosticate often with considerable certainty. The philosophers of old were willing to explain the phenomena by the most vague hypotheses,—by stellar and planetary influences. In those times there were found some who were believed to possess supernatural influence over atmospheric meteors.

Thus the priests of Samothrace,—the Thracean Samos, famous for its deluge, and renowned for the antiquity of its mysteries,—promised auspicious winds to such as consulted their sacred oracle; and Empedocles of Sicily boasted in his song of a knowledge of the mystic art. The priests of Jupiter Lycæus, were wont to sacrifice at the fountain Hagno in Arcadia, in the time of drought,—touching the water with the oaken wand, presently a vapour rose, and forthwith there descended a pleasant rain! Even in more recent times, such powers were believed to be given to mortals; for, in the reign of Constantine, we find Sopater of Apamea put to death because he was supposed to have stilled the winds, and thereby caused the plague which then raged at Constantinople!

3. The atmosphere, though invisible and intangible, is nevertheless a body which cannot elude the grasp of the philosopher. It is a ponderable substance, with whose properties he is familiar. It is obedient to refined analysis, and refuses not to be called by its name when the constituents are again united. It crouches under pressure, regains its original capacity when the load is withdrawn, and becomes more bulky when the weight which it naturally bears is diminished. Thus can he make it heavier or lighter; he can withdraw from or add to its humidity, and vary the amount of its caloric; he can study its electricity, and at will possess himself of that powerful agent. What can he not do with it? But after all—he is ignorant. With Laplace may he say—"that which we know is little, but that which we do not know is immense."

4. The atmosphere was supposed by the ancients to be an elementary body, and was classed with fire, and earth, and water, as ingredients into which all material bodies could be resolved. It was not until about the middle of the 18th century, that Boyle, Hooke, and Mayow, doubted its being a *simple* fluid; and the knell of that cycle had nearly rung, before the discovery was experimentally made by Cavendish, Lavoisier, and Scheele. This was a remarkable scientific epoch: Chemistry awoke from the sleep of alchemy, and one discovery after another rewarded the patient observer for his

persevering labour. Cavendish, Priestley, and Watt, laid the foundation of Pneumatic Chemistry; Lavoisier raised the structure.

5. The atmosphere is composed of aërial fluids, chiefly oxygen[1] and nitrogen,[2] in the ratio of one volume of the former to four of the latter; or, more correctly, one hundred parts of atmospheric air contain 20.8% of oxygen, and 79.2% of nitrogen. Such is the result of numerous analyses by Cavendish,[3] Berthollet,[4] Gay Lussac, Humboldt, Davy, Dumas, Brunner, and Boussingault. Thomson,[5] by chemical analysis of air, and electrical synthesis of water, by means of hydrogen introduced into a measured quantity of atmosphere as proposed by Volta, found the ratio of these gases to be as one to four; and this harmonises with the view of Gay Lussac[6] regarding ratios of the union of gases. Thus employing the atomic theory of Dalton, air would be composed of one atom of oxygen and two atoms of nitrogen, and its atonic weight $=8.013+(2\times 14.19)=36.393$, hydrogen being represented by unity; but if, according to the Continental notation, we take oxygen as the standard, $=100$, then the atomic weight of atmospheric air will be $100+(2\times 177.04)=454.08$.

6. To these gases is added a variable quantity of carbonic acid gas,[7] about one volume to 2000 of atmospheric air. This gas is widely diffused, for M. de Saussure[8] ascertained its presence on the summit of Mont Blanc, and Baron Humboldt[9] detected it in the air collected by Garnerin in a balloon at an altitude of 4280 feet. Saussure[10] found by numerous experimental inquiries that at Chambeisy, near Geneva, in that city, and over the Leman lake, the average quantity was 4.9 by vol. in 10,000, at mid-day. The range was from 3.7 to 6.2. In summer the amount was greater than in winter; and in

[1] *Oxygen*—Lavoisier; *Empyreal air*—Scheele; *Dephlogisticated air*—Priestley; *Vital air*—Condorcet.

[2] *Nitrogen* or *Azote*, the *phlogisticated air* of Priestley.

[3] Phil. Trans. Lond. 1783.

[4] In the year 1802.

[5] First Princip. of Chemistry.

[6] See Mém. d'Arcueil. tom. ii. 233.

[7] *Carbonic acid gas*, the *Fixed air* of Black.

[8] Voyage dans les Alpes, tom. iv. 199.

[9] Jour. de Phys. tom. xlvii. 202.

[10] Annales de Chimie et de Physique, xxxviii. 411; Ib. xliv. 5.

December, January, and February, it bore to June, July, and August the ratio of 77 to 100, the observations being made at noon. He likewise observed that the maximum occurred during the night; that it was greater over a dry than a wet soil; and greatest in the superior strata of the atmosphere. Considerable doubt rests upon the accuracy of these experiments. Thenard[1] found, by means of barytes water, that 10,000 vol. of air contained 3.91 vol. of this gas. Dalton,[2] with lime water, estimated the quantity at 6.8 vol. in 10,000 of atmospheric air. According to recent observations by Boussingault and Levy at Andilly, near Montmorency, sixteen miles from Paris, and in that city, between the 29th September and 20th October 1843, it appears that the quantity of carboinc acid gas in 10,000 volumes of the atmosphere, was at Paris 3.253, and at Andilly 2.989 vol., or as 100 to 92. The experiments were performed at each place at the same hour, and upon the same quantity of air, viz., about 450 pints, which gave at Paris 0.826 grammes, = 12.76 English grains, and at Andilly 0.797 gram. = 12.31 English grains of carbonic acid.[3] Vogel[4] asserts that the atmosphere over the ocean contains less of this gas than over the land.

7. In addition to these gases, aqueous vapours, the product of oxygen and hydrogen chemically combined, and various adventitious odours, are always floating about in inconstant quantities. These chiefly arise from the outcast of our manufactories, and decaying organic products; and were a process of purification not constantly going on in the great laboratory of nature, our atmosphere would be no longer innocuous, and under its deadly influence life would languish and expire. It shall be presently observed, that much oxygen is furnished by the infusoria, and by a process of deoxidation from carbonic acid. Thus, by means of oxygen, which possesses the power of readily combining with all the elements, fluorine probably excepted, and most compound substances, the atmosphere is freed from adventitious matters, and pre-

[1] Traité Elem. de Chimie, tom. i. 303.
[2] Philosophical Mag. xxiii. 354. [3] Dumas,—Acad. de Sc. de Paris.
[4] Annals of Philosophy, No. 5; Journal de Pharmacie, No. ii. 501.

served in a state of purity. According to Baron Liebig,[1] there is always present ammonia[2] derived from the decomposition of organic matters, from which gas, the nitrogen of plants, is supposed to be obtained. From the great affinity of ammonia for water, it will not be found *free* in a humid atmosphere. Its presence in meteoric water may be shewn by adding hydrochloric or sulphuric acids and evaporating nearly to dryness, when the peculiar pungent odour of ammonia will appear on addition of a little lime.[3] According to Gieger[4] it exists in the atmosphere in combination with carbonic acid. The ammonia may become oxidised and give rise to nitrous and nitric acids, occasionally met with in rain. This may be effected in all likelihood by the electricity of thunder-storms. Dr J. Murray[5] has detected nitrous acid in the atmosphere by means of the tincture of Campechia wood. The presence of this acid may explain why milk and other organic substances easily pass to the acetous stage of fermentation during high electric excitement. Cavendish, by passing electricity through atmospheric air in glass globes hermetically sealed, obtained the red fumes of nitrous acid, an effect which may be produced by the electricity of the clouds. Chevallier[6] noticed in the air over Paris, ammonia and organic matters, and in London sulphurous acid. Boussingault[7] adds a very minute quantity of carburetted hydrogen. Hydrochloric acid and its salts have been detected by the shores of the Mediterranean[8] and the Baltic[9]. Air from the bassins de Montfauçon has been observed to contain ammonia and its hydrosulphuret; and that from the fosses d'aisance of Paris

[1] Organ. Chem. of Physiol. and Agricult.

[2] *Ammonia*,—Volatile Alkali. Composed of nitrogen 1 vol. and hydrogen 3 vols., condensing into 2 vols.

[3] The rationale of the process is easily understood. The hydrochloric acid unites with the ammonia through its affinity for that substance, and hydrochlorate of ammonia (muriate) is formed; when to this salt carbonate of lime is added, decomposition takes place, hydrochlorate or muriate of lime results, and the ammonia escapes with the carbonic acid of the lime.

[4] Archiv. des Pharm. xliv. 35.

[5] Phar. Times, vol. i. 259.

[6] Jour. de Pharm. 1835.

[7] Ann. de Ch. et de Phys. 1834, tom. lvii. 171; Ib. 1839, tom. lxxi. 116; Mémoires de l'Institut Royal de France, 23 Août 1834.

[8] Foderé,—Voy. aux Alpes Maritimes, tom. ii. 256.

[9] Vogel of Munich.

acetate and hydrosulphuret of ammonia.[1] In fact, particular circumstances, such as large works of various kinds, the decomposition of vegetable and animal matters, &c., will generally lead to local peculiarities. To these ingredients of the atmosphere Orfila[2] adds electricity, light, and caloric necessary for suspending the substances in the gaseous state.

8. The proportions of oxygen and nitrogen in the atmosphere are the same on the tops of mountains and in the most sheltered valleys. This holds true likewise over the ocean, though Ingenhousz was of opinion that at sea the proportion of the former was greater, and in marshy districts less than that stated. Levy's recent analyses lead him to think that there is a slight but appreciable difference, depending upon the seasons, and physical aspect of the locality.[3] This Danish chemist collected air close to the surface of the ocean, which when compared with that at Copenhagen, and on the coast of Kronberg during sea-breezes, and about 40 feet above the sea, gave the following ratio of oxygen,—1.0000, 1.0143, and 1.0195 respectively. The younger Saussure has analysed air from the summit of Mont Blanc and Geneva ; De Marti, in Spain ; Berthollet, in France and Egypt ; Humboldt, on the Andes, and on the top of Teneriffe ; Davy on the coast of Guinea, and in England ; Gay Lussac, from an altitude of about 23,000 feet, and near the earth ; Boussingault, in South America ; Dumas,[4] at Paris ; Brunner, at Berne ; Stas, at Brussels ; Marignac, at Geneva ; and Martins, on the Faulhorn ; and *uniformity has resulted.* Even the noxious atmosphere of an hospital examined by Séguin, afforded no proof that the usual proportion of these gases was changed. In one of the chief sewers of Paris, however, and this we do not at all wonder at, the analysis gave, oxygen 13.79, nitrogen 81.21, carbonic acid 2.01, and sulphuretted hydrogen 2.99%.[5]

[1] Chevallier,—" Air atmosphérique et hydrosulfate d'ammoniaque, fourni par l'eau de la fosse." Orfila,—Traité de Poisons, tom. ii. 484, 661.

[2] Leçons de Chimie. Bruxel. 1836, p. 55.

[3] Comptes rendus des Séances de l'Acad. des Sciences, tom. xvii. 235-248.

[4] Annal. de Ch. et de Phys., 1841, tom. lxxviii. 257.

[5] Taylor's Med. Jurisprud. 1844, 561.

9. The equable mixture of these gases,[1] though of dissimilar specific gravities, has been ascribed to the principle of resistance of the particles of the same gaseous fluids. Thus the molecules of oxygen are supposed to repel those of the same gas, while those of nitrogen repel in the same manner the molecules of nitrogen. In other words, they mutually mingle, just as if no other gas was present. So long as gases do not act *chemically* on one another, the presence of one does not mechanically prevent the distribution of the other. This theory was proposed when, by experiment, Dalton found the opinion of Berthollet[2] incorrect. Berthollet sought in chemical affinity the explanation, though he was necessitated to assign to it a feeble attraction, barely sufficient to counterbalance the gravitating force of the gases. Sir Isaac Newton[3] reasoned upon the mechanical constitution of the atmosphere, considering the air to be composed of entities, subject to the laws of gravitation, the particles of which resist those adjoining, with forces inversely proportional to the distance. The subject is one of much difficulty, and as yet resting on probabilities. The atmosphere has hitherto resisted every effort to produce its liquefaction.

10. Let us digress, and examine the properties of these gases. They are elastic fluids, clear, colourless, devoid of smell and taste, but no farther do they agree.

Oxygen. The discoverer of this gas was our own Priestley in 1774, though Lavoisier in France, and Scheele in Germany, were carrying on similar experiments at the same time, together yet unknown. It is not quite a century since then. Oxygen is heavier than air, its sp. gr. being as 1.111 to 1.000, or, according to the mean of Dulong, Berzelius, Fourcroy, Vauquelin, Séguin, Kirwan, Lavoisier, Allen, and Pepys, 1.097, to atmospheric air as unity. It is a supporter of combustion,

[1] See Dalton's Syst. of Chem. Philos.; Manchester Memoirs, vol. v.; Edin. Jour. of Sc., vol. iv. 211; Graham on the Diffusion of Gases,—Edin. Roy. Soc. Trans., vol. xii. 1831; Thomson—Phil. Mag. 3d ser. vol. iv. 321; Mitchell on Penetrativeness of Fluids—Amer. Jour. of Med. Sc. vol. vii.

[2] Statique Chimique, 1803; Murray's Chem.

[3] Principia, lib. ii. prop. 23.

and is the most powerful negative electric known, consequently always appears at the positive electrode. This gas has resisted the efforts of chemists to liquefy it, though subjected to the pressure of 58.5 atmospheres, at the temperature of —145° F. Without oxygen life could not be sustained. In it, unmixed with other gas, life flits away with greater rapidity than in common air. Increased frequency of respiration is the immediate sequence, and disease of an inflammatory type follows, in consequence of the blood's becoming more highly oxidised.[1] This is the most abundant of all the elements; it is met with in every rock, rock-salt excepted; in water it forms 89%, and it is an essential constituent in all organic bodies. It has been computed to constitute one-third of the weight of the whole globe.[2]

Nitrogen, or azote, was first observed by Rutherford[3] of Edinburgh in 1772. It is lighter than atmospheric air in the proportion of 0.9727 to 1.0. It neither supports combustion nor does it sustain life, though it plays a most important part in the economy of life.[4]

11. Carbonic acid gas, discovered by Black, is, when pure, colourless and inordorous. It communicates a peculiar taste to water, which it readily impregnates, and to certain wines their sparkling quality. It is heavier than air, in proportion as 1.52 to 1.0, and can be poured from one vessel to another.

[1] Broughton—Quart. Jour. of Sc., April 1830.

[2] Oxygen may be obtained by various processes, but the best is by the application of heat to a mixture of chlorate of potassa and about a sixth of black oxide of manganese, in a glass retort. The gas comes over rapidly and in great purity, while the decomposition is taking place even at a low temperature. Thus with even a small retort and a spirit-lamp, 200 oz. may be obtained in four minutes. In this process the manganese suffers no change, but its presence facilitates, perhaps mechanically, the decomposition of the chlorate,—Mitscherlich; Wilson—Taylor's Scient. Mem.; Turner's Chemistry, 8th ed. 1847, part i. p. 179.

[3] De Aëre Mephitico, 1772.

[4] Nitrogen may thus be easily obtained.—Mix slaked lime with water, and pour the mixture into a saucer, in the centre of which is placed a small cup with ignited sulphur. Over this invert a glass vessel, and allow the process to go on undisturbed. The sulphur as it is consumed abstracts oxygen from the air, becomes sulphurous acid, which the milk of lime absorbs. It may be obtained likewise by burning phosphorus over water, under a glass shade; when extinguished, the aërial fluid will be nitrogen.

Under the pressure of 36 atmospheres at 32° F. it liquefies,[1] and when liberated in this state, so rapid is the evaporation, and intense the cold produced,—148° F., that it assumes the solid form, resembling snow, remaining congealed under the ordinary atmospheric pressure.[2] It is composed of carbon and oxygen. It extinguishes flame, and is speedily destructive to animal life.[3]

12. These gases are not met with in nature *free*, unless we except carbonic acid, and in one instance nitrogen. Nitrogen is given off by the air-volcanoes of Turbaco in South America, described by Humboldt.[4] These volcancitos are about twenty in number, rising like truncated cones to a height of nearly 24 feet, from a base 80 yards in circumference, and form a surface of about 900 square feet. From their small craters air-bubbles, consisting of almost pure nitrogen, are constantly escaping, in number equal to 5 in 2 minutes, and containing from 13 to 14 cubic inches of that gas. In some of the mineral waters of this country, *e. g.* Bath,[5] Buxton,[6] Harrowgate,[7] and Leamington Priors,[8] azote has been met with.

13. Carbonic acid gas is frequently met with in union with water, but more rarely in the form of gaseous springs or *solfataræ.* Many springs charged with this gas might be instanced, *e. g.* Karlsbad in Bohemia, Wiesbaden in Nassau, Bath and Bristol, all which are warm or *thermal;* Seltzer in Nassau, Kilburn,[9] Tunbridge, Harrowgate, and Cheltenham in England, and Pitcaithly in Scotland, which are cold springs. M. Theodore de Saussure has shewn that 100 cubic inches

[1] Professor Faraday.

[2] Thilorier—Ann. de Ch. et de Phys. lx. 427. Improved by Addams of Kensington.

[3] Carbonic acid is disengaged abundantly, when diluted hydro-chloric acid is poured over carbonate of lime (common marble). The acid combines with the lime, and liberates the gas, which being heavier than air, remains at the bottom of the vessel.

[4] Personal Narrative.

[5] Priestley in 1775—Exper. and Observ. on Air, vol. ii. 225.

[6] Dr Pearson; Sir Charles Scudamore, M.D.

[7] Dr Garnet.

[8] Dr Lambe.

[9] Schmeisser—Ph. Tr. lxxxii. 127.

of distilled water, under medium pressure, will, when fully saturated, take up 106 inches of this gas. Henry found the quantity absorbed equalled 108 inches, and Dalton, bulk for bulk.[1] If Berthier[2] is correct in the opinion that the carbonic acid which profusely escapes from many thermal springs, issues independently from the same fissures with the water, then the localities where this gas is afforded in its free state are more numerous than is generally supposed. Karlsbad would in this case rise to the first rank of illustrations. The crater of Vesuvius evolves immense quantities of carbonic acid when in action, and other volcanoes do the same. It occurs in Europe among the fissures of the lava of Auvergne, from Clermont to Royat; it is given off abundantly at the Puits de la Poule, near Neyrac; in the Vivarais, at Driburg under the old castle of Yburg near Paderborn in northern Germany, and largely at the Dünst-höhle near Pyrmont in the same country,[3] where it issues from fissures in the *buntersandstein.*

14. The *Grotto del Cane,* near Naples, is another spot where carbonic acid gas is liberally disengaged.[4] This grotto is situated near the vapour-baths of San Germano, and not far from the famous Agnano lake, supposed to have been the fish-pond of the villa of Lucullus. There the gas, issuing from chinks in the cave, collects at the bottom till it reaches the lower surface of the entrance, whence it flows. It is a grotto fatal to dogs, and other animals of that size, but man may stand erect with impunity. The explanation is easy. The dog being of lower stature than the depth of the cave below the entrance, is fully enveloped in the poisonous exhalations; he breathes the mephitic gas, becomes asphyxiated, and if not withdrawn, expires. The gas escaping by the entrance does not vitiate the air above. The gaseous exhalations from the Grotto del Cane, Pyrmont, and some other places, experience remarkable changes, the cause of which is not fully under-

[1] Thomson's Chem. 5th ed. vol. iii. 58. [2] Ann. de Ch. et de Phys. xix. 25.
[3] Graefe and Walthier's Jour.; Athenæum, No. 341.
[4] See Cobbett's Tour in Italy, &c. Lond. 1830, &c.

stood.[1] This gas issues in considerable quantity from the rocks in the neighbourhood of Brohl near Bonn, and from the small but deep crater-like lake of Laach. It has been computed that 600,000 pounds of this gas are daily evolved from this locality,[2] and there is a vulgar fable that its noxious vapours prove as poisonous to the feathered tribe as those of the far-famed Avernus of Italy.

> "Spelunca alta fuit,.....................
> ....
> Quam super haud ullæ poterant impune volantes
> Tendere iter pennis: talis sese halitus atris
> Faucibus effundens supera ad convexa ferebat."
>
> VIRG. *Æn.* lib. vi. 236.

> "Deep was the cave,........................
> O'er whose unhappy waters, void of light,
> No bird presumes to steer his airy flight;
> Such deadly stenches from the depth arise,
> And streaming sulphur, that infects the skies."
>
> DRYDEN.

Probably Alexander's Cave, near Tabriz in Persia, owes its hurtful exhalations to a similar cause.[3] Pliny seems to refer to the Grotto del Cane, when he mentions that above Puteoli, deadly vapours arose from clefts in the ground.

15. There is a valley in Java called the *Valley of Death*, which doubtless owes its deadly character to the presence of carbonic acid gas in extraordinary abundance, mingled probably with other mephitic vapours. It is thus described by Loudon,[4] who in 1830, made a tour through Java and Madara.

"*Balor, 4th July* 1830.—Early this morning we made an excursion to the extraordinary valley, called by the natives Guwo Upas, or Poisoned Valley; it is three miles from Balor, on the road to Djienz. Mr Daendels had ordered a footpath to be made from the main road to the valley. We took with us two dogs and some fowls, to try experiments in

[1] Dr Mered. Gairdner—Min. and Therm. Springs, p. 59.

[2] Murray's Handb. North. Germ. p. 270.

[3] Athen. No. 221. Jan. 21. 1832.

[4] Jameson's Edin. New Phil. Jour., vol. xii.; Encyc. Brit. 7th ed. vol. xviii. 183.

this poisonous hollow. On ariving at the foot of the mountain we dismounted, and scrambled up the side about a quarter of a mile, holding on by the branches of trees; and we were a good deal fatigued before we got up the path, being very steep and slippery from the fall of rain during the night. When within a few yards of the valley, we experienced a strong nauseous, suffocating smell; but on coming close to its edge, this disagreeable odour left us. We were now all lost in astonishment at the awful scene before us. The valley appeared to be about half a mile in circumference, oval, and the depth from 30 to 35 feet; the bottom quite flat; no vegetation; some very large (in appearance) river-stones; and the whole covered with the skeletons of human beings, tigers, pigs, deer, peacocks, and all sorts of birds. We could not perceive any vapour or any opening in the ground, which last appeared to us to be of a hard sandy substance. It was now proposed by one of the party to enter the valley; but at the spot where we were, this was difficult, at least for me, as one false step would have brought us to eternity, seeing no assistance could be given. We lighted our cigars, and with the assistance of a bamboo we went down within 18 feet of the bottom. Here we did not experience any difficulty in breathing, but an offensive nauseous smell annoyed us. We now fastened a dog to the end of a bamboo 18 feet long, and sent him in; we had our watches in our hands, and in 14 seconds he fell on his back, did not move his limbs or look round, but continued to breathe 18 minutes. We then sent in another, or rather he got loose from the bamboo and walked in to where the other dog was lying. He then stood quite still, and in 10 seconds he fell on his face, and never afterwards moved his limbs; he continued to breathe 7 minutes. We now tried a fowl, which died in a minute and a half. We threw in another, which died before touching the ground. During these experiments, we experienced a heavy shower of rain; but we were so interested by the awful sight before us, that we did not care for getting wet. On the opposite side near a large stone, was the skeleton of a human being, who must have perished on his back with the right arm under his

head. From being exposed to the weather, the bones were bleached as white as ivory. I was anxious to procure this skeleton, but any attempt to get at it would have been madness. After remaining two hours in this Valley of Death, we returned, but found some difficulty in getting out."

16. Let us suppose with some, that atmospheric air is a *chemical* compound, an idea argued against by the late Dr Dalton;[1] or grant with that great philosopher that the gases are merely *mechanically blended*, we cannot too much admire the wisdom of the Creator in adjusting the proportions so exactly for the comfort and preservation of his creatures. We have stated, that 4 vol. of nitrogen and 1 vol. of oxygen form atmospheric air, or to reduce the ratio to the following standard—say, *two* vol. of nitrogen, and *half* a vol. of oxygen, compose the air we breathe. *Two* vol. of nitrogen, and *one* vol. of oxygen, form the nitrous oxide or *laughing-gas* of Davy,—a fluid which, when inhaled for a few minutes, intoxicates; but which would be injurious, if not fatal, if breathed for any length of time. *Two* vol. of nitrogen, and *two* vol. of oxygen, form the nitric oxide,—a gas which cannot be respired, for, coming in contact with the atmosphere, it is instantly converted into a poisonous acid, the nitrous acid recognised by its ruddy fumes. *Two* vol. of nitrogen, and *three* vol. of oxygen, form the hyponitrous acid, which exists only in combination with a base. *Two* vol. of nitrogen, and *four* vol. of oxygen, form the nitrous acid already mentioned. *Two* vol. of nitrogen, and *five* vol. of oxygen, compose nitric acid or aquafortis, one of the most corrosive and deadly poisons. Thus, of *all* the combinations of these two gases, atmospheric air is the *only* one fit for sustaining life! How easily could the destruction of the globe be effected, were the Creator to change the proportions of these fluids!

> "'Tis sweet to muse upon His skill display'd,
> Infinite skill in all that He has made!"
>
> COWPER,—*Retirement.*

17. This leads us to refer to a speculation of M. Adolphe

[1] Syst. of Chem. Philos.

Brongniart,[1] upon the formation of those carboniferous beds which are so widely distributed over our globe, and without which civilization would not have rapidly advanced. To this geologist it has occurred, that, during that era of our earth's history, the atmosphere was much more largely charged with carbonic acid gas than now or previously. During that era, there seems to have been an ascendency in the vegetable over the animal kingdom, for while immense numbers of trees and arborescent ferns and smaller plants existed, scarcely a vestige of land animals is to be found. If we suppose that during that period there was a larger proportion of carbonic acid in the air than now, it would be most favourable to vegetable life, while the excess would be detrimental to that of animal existence. No sooner were those vast coal-fields deposited, than we find a manifestation of animal life, and finally its predominance. We find much luxuriant vegetation in the presence of those waters which are richly charged with carbonic acid gas.[2]

18. It has been shewn, that the proportions of oxygen and nitrogen in our atmosphere are invariable. Whence the source of the supply of the former gas to compensate its consumption by organic life and combustion ? According to Lavoisier and Séguin, an adult man consumes by respiration in 24 hours, 46037 cubic inches, or 32.5 oz. of oxygen. Davy estimates the amount somewhat less, and Menzies slightly greater ; but supposing one of these results to be a near approximation to truth, it is evident that the human race alone require for the purposes of life an enormous quantity of this gas, which is separated in the lungs from the other atmospheric ingredients. Boussingault[3] computes the consumption of oxygen by the horse in the same period at 13 lb. 3.5 oz., and by the cow, at 11 lb. 10.75 oz. During expiration nitrogen is thrown off, and the place of the oxygen nearly supplied by carbonic acid

[1] Annales des Sciences Naturelles, tom. xv.

[2] Schleiden,—Wiegman's Archiv. iii. 1838; Davy,—Consola. in Trav. 3d ed. p. 116.

[3] Ann. de Ch. et de Phys.; Liebig's Organ. Chem.

exhaled, together with aqueous vapour.[1] How, then, are the relative proportions preserved? The expired carbonic acid is absorbed by the vegetable world; its carbon is appropriated as the special food of plants, and by day a larger quantity of oxygen is eliminated than consumed;[2] although during night carbonic acid is given off, it is in a smaller ratio. Here, then, we observe a remarkable reciprocal relation between the vegetable and animal kingdoms. From these facts we are warranted to believe that every tree, plant, and blade of grass contribute their quota to the purification of the atmosphere, and the preservation of the equilibrium of its component parts. But this is not all. Count Rumford long ago discovered that the *infusoria* evolve oxygen; and recently Liebig and others have drawn attention to the fact. The number of those little creatures far exceeds the power of human ken. Creation teems with their existence, yet all so small that naked vision fails to detect their presence.

> "Shall little haughty ignorance pronounce
> His works unwise, of which the smallest part
> Exceeds the narrow vision of her mind?"
>
> THOMSON,—*Summer*, v. 321.

[1] See Lavoisier, Séguin, Davy,—Phil. Tr. 1823; Edwards—De l'Infl. des Agens Phys. sur la Vie, Paris, 1824, p. 420 *et seq.*; Prout, Menzies, Allen, and Pepys,—Schweiger's Journ. i. p. 182, and lvii. p. 337; Ph. Tr. 1809; Despretz,—Ann. de Ch. et de Phys. tom. xxvi. p. 337; Dulong,—Schweiger's Jour. xxxviii. p. 505; Andral, Collard de Martigny,—Jour. de Physiol. tom. iv. et x.; Coutanceau,—Revision des Doct. Physiologiques; Nisten, Spallanzani, Ellis,—Inq. into changes induced on atmos. air, &c.; Humboldt and Provençal,—Mém. d'Arcueil, tom. ii.; Bostock,—Physiol. Ch. vii. sec. 3.; Gavarret, Dumas, Valentine, Brunner, Simon, —Anim. Chem. vol. i., &c.

[2] Priestley, Davy, Ingenhousz, Woodhouse, Senebier, Saussure, Burnett, Liebig, Daubeny, Boussingault,—Economie Rurale, tom. i. pp. 53–68; Johnston,—Agricult. Chem. &c.

CHAPTER II.

19. Figure of the Atmosphere. 20. Its specific gravity. 21. Density decreases with ascent; physical effects therefrom. 22. Height computed by the Thermometer. 23. Boiling point of water under various atmospheric pressures. 24. Sufferings from rarefied air,—Gerard, Wood. 25. Batten, Moorcroft, and Hearsay; Liebig's explanation. 26. Effects of Altitude upon Sound. 27. Height of the atmosphere. 28. Computed by Refraction. 29. Mariotte's law. 30. Illustrated hypothetically. 31. Mean pressure; weight of the entire mass of air. 32 Pascal's experiment on the Puy de Dome; elasticity of the atmosphere. 33. Dove on barometric oscillations. 34. Diurnal tidal waves in the Barometer. 35. Anomalous observations: theory. 36. Other oscillations. 37. Diurnal variation. 38. Annual range. 39. Peculiarities at the Cape and Calcutta. 40. Isobarometric lines of Kämtz. 41. Anomalous movements of the Barometer. 42. Influence of Winds. 43. Explanation of barometric fluctuations.

19. The atmosphere which surrounds our globe is of a figure similar to the earth; hence spheroidal, the equatorial diameter being greater than the polar axis. Though these terrestrial diameters bear the proportion of 300 to 299, we cannot estimate the dimensions of the atmospheric sphere with certainty; the probability however is, that the equatorial bears a greater proportion to the polar diameter than the ratio given.

20. We find that the property of weight possessed by atmospheric air in common with other bodies, was known to the ancients, though subsequently abandoned. Aristotle[1] asserted that a bladder inflated with atmospheric air, weighed more than when empty. The weight of a given quantity has been differently computed by various observers. Perhaps it is not far from the truth, to say that 100 cubic inches at mean tem-

[1] Stanley's Hist. of Philos.,—Aristot. part ii. ch. 7.

perature and density, weigh from 30.2662 to 31.0 grains,[1] which is equal to 523 grains or 1.195 oz. avoid. for every cubic foot Prout calculates the weight of 100 cubic inches of dry air, the barometer being 30 inches and thermometer 60° F. at 31.0117 grains. Dalton and Henry compute it at 31; and Shuckburgh at 30.5 grains.[2] Atmospheric air bears to water the relative weight of 0.00119 to 1.0, *i.e.* bulk for bulk, air is 840 times lighter than pure water. Hooke gives the proportion somewhat lower. On the 10th February 1664, he found that a pint of water weighed 8.21872 oz., and the same measure of air 8.28947 grains, and determined the specific gravity[3] of air to be very nearly 0.0011765. According to Lavoisier, with the barometer at 29.85 inches and thermometer at 54.5°, the specific gravity of the atmosphere is 0.0012308, (vide 120).

21. As we ascend, the atmosphere gradually decreases in density, and on lofty situations the effects of its rarity are disagreeably manifested. Acosta in the 16th century described the violent symptoms which he and his companions experienced on the mountains of Peru;[4] and very recently, Dr J. J. Von Tschudi,[5] on the Cordilleras. Baron Humboldt,[6] at an altitude of about 16,000 feet, felt overcome with fatigue, blood burst from his lips and ears, and respiration was affected. A fire was kindled and kept burning with greater difficulty than on the plain below,—a fact which Marco Paulo observed on the mountains of Asia so early as the 13th century. Water, which in the plain boiled at the ordinary temperature of 212°

[1] As 100 cubic inches of oxygen weigh 33.90 grains and 100 cubic inches of nitrogen weigh 29.655 grains, it follows that 100 cubic inches of atmospheric air $= \left\{33.90 + (29.65 \times 4)\right\} \div 5 = 30.5$ grains.

[2] Phil. Tr. vol. lxvii. p. 560; Turner's Chem.

[3] The sp. gr. of a substance equals its weight divided by its volume, hence, if x, w, v, and x', w', v', represent the sp. gr., weight and volume of air and water respectively, it follows that, bulk for bulk, $x : x' = \frac{w}{v} : \frac{w'}{v'}$ or $x : x' = w : w'$; and if the weights are the same, $x : x' = \frac{1}{v} : \frac{1}{v'}$. Hence, the volumes being equal, the sp. gr. is directly as the weight, and the weights being equal, inversely as the volume.

[4] Hist. Nat. de las Indias.

[5] Travels in Peru—Ross. Lond. 1847.

[6] Ed. Phil. Jour.; Athen. No. 524, p. 833.

F., boiled on one of the summits of the Andes at 175° F., where only $\frac{13}{30}$ths of the atmosphere exerts its pressure. Saussure found water boil at 86.24° C., or nearly 187° F. on Mont Blanc; while in the valley below, it boiled at 101.62° C. or 214°.9 F., a difference of 27.684 degrees of Fahrenheit's thermometer. The barometer stood at 30.534 English inches on the plain, and 17.136 inches on the mountain top. On the Great St Bernard, elevated 11,006 feet, water boils at 190° F. On the summit of Ben-Nevis, elevated 4358 feet, it boils at 203.8° F., the temperature being 30° on the mountain, and 35° on the plain.[1] A curious anecdote, shewing the effect of lofty elevation upon the temperature of boiling water, is told by Mr Darwin of the Beagle, who in 1835 crossed the Andes. The altitude was so great, and the boiling point so low, that "our potatoes, after remaining for some hours in the boiling water, were nearly as hard as ever. The pot was left on the fire all night, and next morning it was boiled again; but yet the potatoes were not cooked. I found out this, by overhearing my two companions discussing the cause; they had come to the simple conclusion, that the potatoes were bewitched, or that the pot, which was a new one, did not choose to boil them." On the Nonewara mountain, Baron Hügel[2] had much difficulty in melting ice in consequence of its passing off in vapour without dissolving: at last he found the boiling point of water to be 188°.

22. In estimating the height of any mountain by the thermometer, a difference of one degree in the boiling point of water, between that upon the summit and in the plain, corresponds to an altitude of about 530 feet, the state of the atmosphere being unchanged during the observations. The Rev. F. J. H. Wollaston,[3] by the invention of a thermometer, each degree of which is divided into 1000 parts, has brought this method to considerable perfection.

23. Seeing that the density of the atmosphere deter-

[1] According to Robison, fluids boil *in vacuo* at 140 degrees lower than in open air. Black's Lect. v. i. p. 151.

[2] Trav. in Kashmér and the Panjáb—Jervis, Lond. 1845, p. 167.

[3] Phil. Tr. 1817.

mines the point of ebullition, the height of the barometer on the plain will indicate even there a variation in the boiling point. Thus, the mercury being at 27.7 English inches, water will boil at 208° F.; at 28.2 inches at 209°; at 28.8 inches at 210°; at 29.4 inches at 211°; at 30.0 inches at 212°; at 30.6 inches at 213°; at 31.2 inches at 214°; and at 31.8 inches at 215°.

24. The brothers Gerard, in their travels among the Himmalehs, frequently felt the inconvenience of atmospheric rarity. One of them thus describes his feelings:[1]—"Our elevation was now upwards of 15,000 feet, although we had ascended in company with the river against its current. Here only began our toils, and we scaled the slope of the mountain slowly; respiration was laborious, and we felt exhausted at every step. The crest of the pass was not visible, and we saw no limit to our exertions. The road inclined at an angle of 30°, and passed under vast ledges of limestone. The projections frowned above us in new and horrid forms, and our situation was different from any thing we had yet experienced. Long before we got up, we were troubled with severe headaches, and our respiration became so hurried and oppressive that we were compelled to sit down every few yards, and even then we could scarcely inhale a sufficient supply of air. The least motion was accompanied with extreme debility, and a depression of spirits; and thus we laboured for two miles." Lieutenant Wood[2] at Pamer in central Asia,—the Bam-i-duniah, or roof of the world, (N. lat. 37° 27′, E. long. 73° 40′), perhaps the most lofty *plateau* on the globe,—endeavouring to break the ice on the lake of Sirikol, to measure its depth, found a few strokes with the axe exhausted the men, and continued work was impracticable. Mr Green and Mr Rush, who ascended in a balloon in Sept. 1838 to the height of 27,136 feet, or $5\frac{1}{7}$ miles above the sea,—the greatest altitude we believe yet attained,—felt comparatively little inconvenience, though the first 11,000 feet were ascended in 7 minutes. This arose evidently from the almost absolute repose of the body. Mr Rush suffered

[1] Asiatic Journal.
[2] Personal Narrative of Journey to Source of the Oxus. Lond. 1841.

only from the cold, and Mr Green felt his respiration hurried only when he exerted himself.[1]

25. Captain Batten says the feelings experienced by him on the Nittee Pass were far more severe than *angina pectoris.* Moorcroft,[2] describing an exploring expedition among the Himmalehs, when accompanied by Captain Hearsay and a Hindu, says that his breathing was quickened, and he was obliged to stop every four or five steps; he felt a sense of fulness in the head and giddiness. On ascending farther, the oppression increased, there was a sense of sleep, accompanied by a feeling of suffocation, and sighing became frequent and distressing. The natives attribute these sensations, which are felt by the animal creation likewise, to a poisonous atmosphere which they call *Biskeehuiva,* conceived to arise from the odours of certain flowers. Mr Lyell tells us that the English greyhounds, taken out for the Real del Monte Company in Mexico, when hunting at an altitude of 9000 feet, where the barometer does not rise above 19 inches, were unable to bear the fatigues of the chase, and fell down gasping in such an attenuated atmosphere; but, as if nature would provide for the altered condition of the race, the whelps felt no inconvenience from its rarity. The inhabitants of the Alps are said to be very subject to bronchial hæmoptysis from diminished atmospheric pressure.[3] Although the late lamented Hon. James Erskine Murray[4] did not perceive, on the Mont Perdu, at an altitude of 11,000 feet, any disagreeable inconvenience, yet, the elevations of European mountains and those of South America and Asia being so dissimilar, we must to that circumstance attribute in a great measure his freedom from the peculiar sensations which others have experienced. Dr Martin Barry[5] has given the following account of his own feelings on ascending Mont Blanc in 1834. At an altitude of 12,000 feet, and between that and 14,700, he

[1] Jameson's Jour. July 1840, vol. xxix. p. 44, note.
[2] Asiatic Researches, vol. xii.
[3] Hasse's Patholog. Anat. 1846, p. 242; Michéa—Gaz. des Hôpit., 1840, No. 41.
[4] Summer in Pyrenees, 2d ed. vol. ii. p. 68.
[5] Ascent of Mont Blanc, 1836, p. 104.

experienced "great dryness,—in some parts a lurid colour, and constriction of the skin. Intense thirst. Incipient loss of appetite." There was increased evaporation, and the solar rays were more powerful. At 14,700 feet, the appetite was completely lost, but he did not feel fatigue. At 15,000, there was exhaustion and difficult breathing, "coming on suddenly, after 20–30 steps, up a plane of 30° of indurated snow having a slippery surface." These effects passed off on standing still and taking a few deep inspirations. At 15,500 feet, he experienced extreme exhaustion, greater difficulty of respiration, a tendency to syncope, and utter indifference; these feelings ceasing with rest and deep inspirations. On the summit, at an altitude of 15,666 feet, his "breathing was not at all affected during an hour and quarter at rest, or when taking moderate exercise on a horizontal surface;" the barometer was then 17.05, and the air-thermometer at 2–5 P.M. about 30° F. On his descent the appetite returned at 10,000 feet, but the thirst continued. *Subsequently*, no collapse followed. Dr Le Pileur, who with MM. Bravais and Martins ascended Mont Blanc in 1844, suffered most during the first hour after the ascent was accomplished.[1] "In climbing high mountains," says Baron Liebig,[2] "where, in consequence of the respiration of a highly rarefied atmosphere, much less oxygen is conveyed to the blood, in equal times, than in the valleys or at the level of the sea, the change of matter diminishes in the same ratio, and with it the amount of force available for mechanical purposes. For the most part, drowsiness and want of force for mechanical exertions come on; after twenty or thirty steps, fatigue compels us to a fresh accumulation of force by means of rest—absorption of oxygen without waste of force in voluntary motions."

26. Highly attenuated air enfeebles the intensity of sound. Thus, Saussure on the summit of Mont Blanc, Schultes on the Great Glockner in the Tyrol, and others on the Monte Rosa, at an altitude of 13,000 feet, have made observations to this effect. In Silliman's Journal, where a night on the summit of Mont Blanc is described, it is stated, that while upon the

[1] Athen. No. 916. [2] Organ. Chem. Physiol. and Pathol., p. 238.

mountain, a severe thunder-storm occurred in the valley. The lightning was distinctly seen, but no sound reached the ear. In Chamouni, the peals were loud and numerous.

27. Among the ancients, an attempt to compute the height of the atmosphere was made by Posidonius the stoic, who calculated its altitude at 800 stadia, or 100 miles. Were the atmosphere throughout of equal density with that upon the earth's surface, it would extend upwards to a height of five miles. This result is thus obtained. The barometer standing at 30 inches at the sea level, and 30 inches minus nearly a tenth at the height of 87 feet, it is presumed that by elevating the instrument 30 times 87, the mercury will sink 30 times a tenth, or 3 inches; by raising the barometer still higher, say 300 times 87 feet, or 5 miles, the mercury will theoretically have sunk to the bottom of the tube, an indication that the atmosphere has no longer an appreciable weight. But as the rarity of atmospheric air increases with the ascent, we are possessed of no perfect data for arriving at a correct conclusion of its real height. It will be shewn hereafter that temperature falls as we ascend; but even in this fact we can find no better data for the solution of the question, for we know little of the thermic curve in the lofty regions of the atmosphere.

28. We possess, however, a clew to the loftiest altitude of air possessing an appreciable density, though not to its absolute limit, in its powers of refracting the solar beams. It may be easily shewn by a trigonometrical proportion, that this power expires at nearly 45 miles above the ground.[1] At that great

[1] The sun having descended 18°, it may be easily shewn, that a line from the centre of the earth to the point in the highest regions of the atmosphere illuminated by his rays, will become the *secant* of 9°, the horizon being *tangent* to the circle, and the observer in the right angle of the triangle. Hence,

$$\text{Radius} : \text{Sec. } 9^\circ = \text{Rad. of earth} : \text{Hypothenuse}$$

$$\therefore \frac{\text{Sec. } 9^\circ \times 3970}{\text{Radius}} = \text{Hypothenuse}; \textit{ i. e.}$$

10.0053801, or the Log. sec. 9°, *into*
3.5987905, or the Log. earth's rad. (3970), *equals*

13.6041706, *which divided by*
10.0000000, or the Log. radius, *gives*

3.6041706 = 4019, *the Hypothenuse.* But the hypothenuse equals the earth's radius *plus* the height of the atmosphere, consequently 4019 − 3970 = 49, the altitude

height the air is so highly rarefied as to be no longer able to refract the rays of the setting sun, and darkness closes the earth as in a mantle,—

> "Night, sable goddess! from her ebon throne,
> In rayless majesty, now stretches forth
> Her leaden sceptre o'er a slumb'ring world.
> Silence how dead! and darkness how profound!
> Nor eye, nor list'ning ear, an object finds;
> Creation sleeps."
>
> YOUNG,—*Night Thoughts.*

This height is farther confirmed by astronomical calculations.

29. Believing that the atmosphere is composed of entities or ultimate atoms, it is evident that a limit does exist; for the force of gravity, drawing each towards the earth's centre, must be greater than the repulsive power of the individual particles, in proportion to the density, and exactly where these forces balance, the extreme boundary will be found.[1] Above this, probably an ether spreads through the planetary regions, meeting the upper limits of the atmospheres of other globes, and stretching forth to the remotest space. Mariotte discovered the law of atmospheric elasticity, that the density or volume of a given quantity of air is inversely as the pressure.[2] Its density at any altitude may be easily found, for as the elevation is increased in arithmetical progression; the density is decreased in geometrical progression, in other words, supposing the density to be 1.000, the height is as the loga

required. Forty-nine miles would then be the true elevation of our atmosphere, were the data upon which this computation is founded strictly correct; but the angle used is rather too much, and the radius slightly in excess; allowing for corrections, we have then 45 as the required height, deduced by trigonometry from the refractive powers of our atmosphere.

[1] See Wollaston—Ph. Tr. 1822; Ivory—ib. 1823; Dalton—ib. 1826; D'Alembert —Op. tom. vi.; Laplace—Méc. Cél. liv. iii. chap. 7.

[2] Huygens, as early as 1662, is supposed to have been acquainted with this law; a Dutch Almanack of that date records it in MS. In 1686, Halley demonstrated the proposition by the properties of the hyperbola and its asymptotes. Hence the mode of computing altitudes by barometric indications. See various papers in Phil. Tr. *passim*, by Halley, Derham, Desagulier, Scheuchzer, Shuckburgh, Evelyn, Roy: Playfair—Ed. Roy. Soc. Tr. v. i. 87; Leslie—Geom. Notes and Illust.; Euler —Mem. Acad., Berlin, 1753, p. 114; Laplace—Méc. Cél.; Deluc—Rech. sur les Modifica. de l'Atmosphere.

rithm of the density. Thus, supposing the density to be 1 at the height of 1 mile, it will at 2 miles equal 0.794; at 3 miles, =0.631; at 4 miles, =0.501; at 5 miles, =0.398; at 6 miles, =0.316; at 9 miles, =0.158; at 10 miles, =0.126; or, assuming the density as unity at the surface of the earth, it will be $\frac{1}{4}$th at 7 miles; $\frac{1}{16}$th at 14 miles; $\frac{1}{64}$th at 21 miles; $\frac{1}{256}$th at 28 miles, and so on progressively.[1]

30. Let us imagine a hollow sphere of such magnitude that the planet Saturn, whose distance from the Sun is nearly 900 millions of miles, could perform its solar revolutions within; one single cubic inch of air as rarefied at an altitude of 500 miles would fill it entirely ![2] That the eye may behold the vastness of this amount, we give the sum numerically,[3]— 3,053,635,200,000,000,000,000,000,000, or three thousand and fifty-three quadrillions, six hundred and thirty-five thousand, two hundred trillions of cubic miles,—English notation.

31. At the level of the sea, the average height of the barometer equals 29.95 inches; at London, =29.88 inches; and at Paris, =29.77 English inches. This is so nearly 30 inches, or 762 French millimetres, that, excepting where very great accuracy is required, 30 is assumed the mean. We have reason to believe that this is the mean pressure over the globe,[4] although some interesting anomalies have been observed,[5] *e.g.* by Erman,[6] in the east of Siberia; Von Buch, on the Baltic; King,[7] in the Straits of Magellan; also in Central Asia, shewing that the Caspian Sea, the Aral Lake, and a vast extent of sandy *steppe*, are considerably below the level of the Mediterranean and Euxine.[8] In other words, the weight of a column of air upwards to the utmost limit of the atmosphere, incumbent on

[1] *Decimally* we read,—at 7 miles = 0.25: at 14 = 0,0625; at 21 = 0.015625; at 28 = 0.00390625; &c.

[2] Ferguson—Lect. on Select Subj. vol. i. p. 194. Ed. 1805.

[3] The calculation may be thus made. Let a = the diameter of the circle of Saturn's revolution or orbit, and let x = the contents of the sphere whose diameter is a; a = 1,800,000,000 miles. Then $x = a^3 \times \frac{2}{3}\ 0.7854 = 0.5236\ a^3$.

[4] Vide Humboldt's Rélation Historique, 4to, tom. iii.

[5] Forbes—Rep. Brit. Assoc., vol. i. p. 228.

[6] Poggendorff's Annalen. Oct. 1829.

[7] Jour. of Roy. Geog. Soc. i. p. 172.

[8] Three hundred feet—Parrot; 83.5 feet—Fuss, Savitch and Sabler, *Russians.*

a determinate horizontal surface, is exactly the weight of the column of mercury in the tube of the barometer, providing the calibre of the instrument is equal to the given surface; and thus the weight of the entire atmosphere is equal to a sea of mercury covering the superficies of our globe to the depth of about 30 inches. This pressure is equal to nearly 14.6 lb. avoirdupois upon each square inch, or 58,611,548,160 lb. upon every square mile. The pressure of the atmosphere may be thus estimated at about 8 oz. avoirdupois for every inch of mercurial elevation of the barometer. The absolute weight of the atmosphere, assuming the superficies of our globe to be 790,116,426,647,756,800 square inches, amounts to the enormous sum of 11,456,688,186,392,473,600 lb.; equivalent, according to Dr Cotes, to the weight of a globe of lead sixty miles in diameter. Pascal[1] computes the whole mass of air at 8,983,889,440,000,000,000 lb. French. Thus the weight of our atmosphere is equal to above eleven trillions of lb., *English notation*,[2] a sum which words may express and figures tabulate, but the mind cannot appreciate. It grasps a phantom when thinking it is dealing with reality. Reduce this amazing weight to tons, and the mind is still unable to conceive the full value of the product,—5,114,592,940,353,782.85 tons, *i. e.*, five thousand, one hundred and fourteen billions, five hundred and ninety-two thousand, nine hundred and forty millions, three hundred and fifty-three thousand, seven hundred and eighty-two tons! Compared with the weight of the globe, this mighty sum dwindles to insignificance. Unite the two, and none but an Almighty mind can form an adequate conception,—none but an Almighty arm could hurl it through space, and give to its motions a regularity obedient to fixed laws. The same Almighty power alone could institute those laws.

[1] De la Pesanteur de la Masse de l'Air.

[2] The English and French notations are very different after the millioneth. Thus according to English notation,—a million = a thousand thousands; a billion = a *million* millions; a trillion = a *million* billions; a quadrillion = a *million* trillions, &c., counting *by millions*. But the French enumerate *by thousands*, thus, according to French notation, a million = a thousand thousands; a billion = a *thousand* millions; a trillion = a *thousand* billions, &c.

32. In order to prove the elasticity, compressibility, and equal pressure of air on all sides, and by its weight on all surrounding objects, Pascal carried to the summit of the Puy de Dome in Auvergne, a balloon half inflated. As he ascended, it expanded in proportion as the weight of air pressing without was diminished, till it became upon the mountain top fully distended. Descending, the same phenomena appeared in inverted order. The compressibility and elasticity of air were in 1662 demonstrated in this country by Boyle, and subsequently by Mariotte in France. Recently the experiments have been extended by Oersted,[1] Arago, and Dulong. An experiment similar to that of Pascal was performed in Yorkshire on Ingleborough hill by Dausson, towards the close of the 17th century.[2]

33. The pressure of the atmosphere is subject to many variations, indicated by oscillations in the barometer. Professor Dove[3] assigns these to the difference in the velocity of two great atmospheric currents, arising from the extremes of temperature upon the earth, and moving in opposite directions through the unequal rotatory velocity of the equatorial and polar regions—the equatorial taking a westerly, the polar an easterly direction.

34. That change in the atmospheric pressure which is most regular, is a daily oscillation independent of temperature and humidity. This phenomenon attracted the notice of Beale so early as 1666; and in 1740, it was made the object of daily observation by Boudier in India. This tidal wave is highest at 9 P.M. and 9 A.M.; and lowest at 4 P.M. and 4 A.M. Geographical position and the season, slightly modify the cycle. Although these diurnal oscillations occur in all regions, it is in the tropics that they are most distinctly seen, amounting there to about one-eighteenth of an inch with each fluctuation; and they have been observed to reach the maximum, when

[1] Edin. Jour. of Sc. iv. 224.

[2] Nat. Hist. of Lancashire, &c., by Dr C. Leigh. Fol. 1700, Oxford. Ingleborough is in the West Riding of Yorkshire. It rises 2361 feet above the sea; consequently is very nearly half the height of the Puy de Dome.

[3] Meteorologische Untersuchungen. 1837.

there is the smallest force of sea and land breezes; while the minimum depressions take place, when these winds blow with greatest intensity. The amplitude of these oscillations varies with the latitude: thus from the equator to the poles this horary movement gradually decreases from 0.1043 to — 0.015 of an inch. The oscillation becomes *zero*, i. e. changes from *positive* to *negative*, in lat. 64° 8′, as has been shewn by Professor Forbes.[1] Daniell and some others have remarked that the diurnal wave is modified by altitude. Horner noticed this at Zurich; Eschmann and Kämtz on the Rigi; and Bravais, Martins and Kämtz on the Faulhorn. The difference is both in amplitude and epoch.

35. Lieut.-Col. Sabine observes, that in situations remarkable from their physical position for great dryness, as in Russia between Europe and Asia, only one series of diurnal oscillations takes place, and these maxima and minima occur at the extremes of daily temperature. The same has been noticed at Greenwich near the ocean; at Prague, in a central part of Europe, removed to a distance from oceanic influence; and also at Toronto in Upper Canada. But it is not in temperate regions alone that this is observable; the same peculiarity has been detected within the tropics.[2] The explanation is not difficult. As the air is rarefied by the increase of heat, the ascending current diminishes the statical pressure below, and the mercury falls; while the reverse of this takes place at the coldest period of the day,—the statical pressure being increased by the descending current of cold particles, and the mercury elevated. In those places where the double series of tidal waves is met with, Sabine explains one of them in this manner, and attributes the other to the influence of temperature upon the tension of aqueous vapour

[1] Humboldt,—Rélat. Hist. tom. iii.; Cosmos,—Sabine, vol. i. 309; Bouvard,—Biblioth. Univ. 1829; Ph. Tr. 1828, 1831; Carlini,—Memorie della Soc. Ital. tom. xx; Hallström,—Pog. Annal. 1826; Hansteen,—Bul. des Sc. Mathématique, ix.; Forbes,—Ed. Trans. v. xii., Edin. Jour. of Sc. 1823, 1832; Kämtz and Martins' Météorologie, Tables; Sabine,—Brit. Assoc. at York; Rep. Brit. Assoc. 1844. p. 42–62.

[2] Sabine—Rep. Brit. Assoc. 1845, p. 73–82; Cosmos—note by Sabine, vol. i. p. 460; Dove,—Mem. read to Acad. of Sc. Berlin, Mar. 1846.

in the atmosphere, which will produce a similar result, but at different diurnal periods; that is, the maximum vaporic force will occur at the hottest, and the minimum at the coldest hour of the day. By the combination and converse actions of these forces, the phenomena in question are produced. Thus we have united in this theory of the diurnal barometric waves, the calorific action of the sun, suspected by Bouguer, received by Laplace, and surmised by Bouvard, with the hypothesis of Dove[1] of the changing tension of aqueous vapours in the atmosphere under the influence of a fluctuating temperature. By some it has been supposed that these waves are caused by lunar attraction, like ocean-tides; but Bouvard[2] has shewn that the moon's influence is not greater than a force which would elevate the mercury 0.018 of a millimetre at Paris, or 0.00070866 Eng. inch: Laplace[3] considers it not yet determined. Nevertheless, from daily observations at St Helena, Sabine found that on an average the mercury was 0.004 inch higher at the time when the moon crossed the meridian, above and below the horizon, than when she is midway between these limits, and that the progression was uninterrupted between the maxima and minima. In addition, then, to the forces described, we must add a feeble influence from our satellite, as operating to produce those diurnal barometric waves.

36. Besides this tidal oscillation, the barometer is subject to a constant variation, arising chiefly from alternations in temperature and fluctuations of the winds,[4] although it were more philosophical to refer these oscillations to their ultimate cause — calorific impressions. We have already mentioned that the mean height of the barometer at the sea-level, for all latitudes, is very nearly 29.95 English inches; at the equator it is somewhat less, and appears to reach the maximum about

[1] Pog. Annal. 1831.

[2] Mém. de l'Acad. des Sc. 1827, tom. vii. 267.

[3] Méc. Céleste, tom. v. Supp. 30.

[4] Tables or cards of the barometer and winds, are termed *barometric-windroses*, from *windrose*, the rose of the compass, upon which the direction of the winds is marked—German.

the 30.5th parallel.[1] The seasons of the year exercise an influence, the atmospheric pressure being less in summer than in winter. It was observed by Dr Beale that, *cæteris paribus*, the barometer is lower in warm than in cold weather, and Kämtz notices the same. In January 1820 this was remarkably illustrated.[2] At Kinfauns, Perthshire, the Rev. Dr Gordon observed the thermometer fall to 18.5° F. on the 8–9th of that month, while at 9 A.M. of the 9th the barometer stood at 30.85 inches; the locality is 185 feet above the sea, consequently the atmospheric pressure must have been above 31 inches: at the same time, the barometer at Leith, 60 feet above the sea, was 30.999 inches. On the 17–18th of the same month the temperature fell at Perth to — 10° F. or 42° below the freezing point of water.

37. The diurnal range within the tropics is seldom more than one-twentieth of an inch, but in the temperate regions its daily fluctuations are more considerable. The range is greater on the coast than upon a mountain; and generally in the inverse ratio of the elevation. Sir John Herschel[3] observes, that from either tropic to the equator the barometer falls steadily; so that the mean equatorial altitude of the mercury is about .2 of an inch lower than at the entrance to the tropics. The physical cause is the upward suction occasioned by an overflow of air to the extra-tropical latitudes, not immediately compensated for by the undercurrent of the trade winds. "It is," says he, "a dynamical result into which time enters as an essential element. In this, as in the tides, equilibruim is not established *instanter*, and this gives room for the development of appreciable differences of tension in different parts of the circuit."[4]

38. Within the tropics the annual range does not exceed the quarter of an inch, while in temperate climes it oscillates between the 28th and 31st inches. Thus, at Seringapatam,

[1] Schouw and Poggendorff's Table—Comptes rendus de l'Acad. des Sciences. 1836, tom. ii. 573.

[2] Ed. Phil. Jour. vol. ii. p. 335.

[3] Athen. 1834. No. 364, p. 767; Ib. 1835, No. 391, p. 320.

[4] Observ. during Voyage to Cape of Good Hope—Athen. No. 391.

in N. lat. 12° 26′, the annual differential range equals .22 in.; at Calcutta, in lat. 22° 41′ = .33 in.; at Funchal, in lat. 32° = .41 in.; at the Cape of Good Hope, in S. lat. 34° 25′ = .49 in.; at Rome, in N. lat. 41° 55 = .67 in.; at Milan, in lat. 45° 28′ = .76 in.; at Vienna, in lat. 48° 12′ = .8 in.; at Paris, in lat. 48° 50′ = .93 in.; at Dover, in lat. 51° 8′ = 1 in.; at London, in lat. 51° 31′ = 1.09 in.; at Liverpool, in lat. 53° 23′ = 1.2 in.; at Edinburgh, in lat. 55° 57′ = 1.2 in.; at Moscow, in lat. 55° 42′ = .95 in.; at St Petersburgh, in lat. 59° 56′ = 1.25 in.; at Bergen, in lat. 60° 23′ = 1.23 in.; at Abo, in lat. 60° 26′ = 1.18 in.; and in Iceland, in lat. 65° = 1.5 inches. The range is greatest at the sea-level and on mountains, and also greater in winter than in summer. At Kendal, during six years' observations,—from 1788 to 1793 inclusive—the mean *space moved through* by the mercury in the barometer, observed three times a-day, was 8.15 inches from October to March, and 5.37 inches from April to September. The mean *annual* changes during the same period amounted to 81.18 inches; the greatest being 88.66 inches in 1792, and the least 71.63 inches in 1788. The total amount of space oscillated through during those years was 487.08 inches.[1] It may be remarked *en passant*, that more rain falls at Kendal than in any other place in the kingdom; thus, during the same period of observation, the rain at Dover, Liverpool, and Kendal, was 37.5, 34.4, and 61.2 inches respectively.

39. At the Cape of Good Hope the barometer stands higher in July than in January by 0.3 inch; while at Calcutta it is higher in January than in July by 0.52 inch; and these fluctuations are exceedingly regular. Sir John Herschel explains it by the fact, that as the locality is more heated over which the sun's rays are vertical, than that where they fall obliquely, so there is an annual transfer of a mass of air from one hemisphere to another.[2]

40. Kämtz[3] has suggested lines to connect places upon the

[1] Dalton—Manch. Mem. vol. iv. p. 547.

[2] Herschel from obs. of 57m. by Capt. Bance at Cape Town, and of Princep's Calcutta Reg. of 30m.; Athen. No. 391, p. 320.

[3] Lehrbuch der Meteorologie; Jahrb. der Physik und Chemie, 1827; Bulletin des Sc. Mathémat. tom. x. p. 199.

globe which exhibit the same average difference between the extremes of monthly barometric indications, and these are termed *Isobarometric lines.* The distribution of land, the proximity of lofty mountains, prevailing winds and oceanic currents, produce inflections in these lines as remarkable as in the isothermal lines of Baron Humboldt. For example, the isobarometric line[1] of 4.51 millimetres = 0.18 English inch, passes through Eastern America, in lat. 15° 33′; Western Europe, in lat. 15° 9′; Germany and Italy, in lat. 21° 15′; and European Russia, in lat. 23° 36′. That of 0.71 English inch, passes through the New Continent, in lat. 36° 14′, cutting the southern part of Chesapeake Bay; it rises suddenly, and we find it in Europe between N. lat. 42° 14′ and 45° 51′, and in Asia in lat. 46° 34′. That of 1.24 inches is found in Eastern America, in lat. 52° 21′, to the south of Labrador; it crosses the north of Scotland and south of Norway, appearing in Europe in lat. 57° 47′— 68° 50′.

41. At Edinburgh, on the morning of the 7th January 1839, the writer drew the attention of a friend to a remarkable depression of the barometer. On that occasion the late Sir John Robison noted it at 27.6 inches. Water would then have boiled in the open air at about 208° F. The minimum depression was observed between 5 and 6 A.M.; at Altona the barometer fell on the same day to 28.2 English inches at 8.7 P.M., and reached the minimum towards midnight, though it was not so low as at Edinburgh.[2] Upon the 13th January 1843 the mercury again fell so low as 27.75 inches at Edinburgh. The weather was calm all afternoon, but in the English Channel and Irish Sea it blew a hurricane: nearly 500 lives were lost, and 180 vessels wrecked. The barometer fell at Christmas 1821 to 27.80 inches, and this great depression extended over a vast tract. Professors Dove and Brandes[3] determined its course over Europe. At Geneva,[4] where the mean height is 26 inches 11 lines *French*, it fell to 25 inches

[1] Vorlesungen über Meteorol.

[2] Schumacher—Compt. rend. 1839, tom. viii. p. 176, 309.

[3] Brandes—Ann. of Philos. vol. xx. p. 263.

[4] Pictet.—Bib. Univ. Dec. 1821, and Jan. 1822; Ph. Tr. 1822. Part i. 113.

8 lines; the depression was accompanied by a storm of thunder, lightning, wind, rain, and hail, which extended over France and Germany. The night before, a bolis, having the apparent diameter of the moon, was seen at Frankfort and Bamberg, exploding with a loud noise. This extraordinary depression was thought to be connected with the volcanic eruption of Eyafjeld-Jokkul in Iceland: an earthquake was felt at Mayence. In 1763, on November 22. 1768, and January 18. 1784, it fell nearly as low at Geneva. During the earthquakes of Calabria in March 1783, the barometer fell to 27.88 inches. On the forenoon of November 23. 1824, the mercury fell in this country to 27.90 inches. These anomalous depressions are deeply interesting, for they warn us of conflicting winds even at enormous distances. Previous to the earthquake at Lisbon in November 1755, the barometer was remarkably affected in this country, and the waters of Loch Lomond and Loch Ness rose and fell repeatedly on the day of that awful calamity. On October 13–14. 1837, at London the barometer rose to 30.94 inches, and on December 26–27. 1840 to 30.97 inches.

42. The influence of winds upon the barometer is worthy of peculiar attention. Kämtz[1] gives us the result of observations at London, Paris, Middleburg, Hamburg, Copenhagen, Minden, Apenrade, Carlsruhe, Berlin, Halle, Vienna, Buda, Stockholm, Petersburgh, and Moscow. Of these we shall select London, where, with the—

N. wind, the barometer averages	759.20 millimetres,	= 29.89	Eng. in.
N.E.	760.71 ...	= 29.95	...
E.	758.93 ...	= 29.88	...
S.E.	756.83 ...	= 29.78	...
S.	754.37 ...	= 29.69	...
S.W.	755.25 ...	= 29.73	...
W.	757.28 ...	= 29.81	...
N.W....	758.03 ...	= 29.84	..
Mean	757.58 ...	= 29.826	...

[1] Vorlesungen über Meteorol.

According to Pouillet[1] the observations made at Paris between 1816–27, gave the following results—

Wind.	No. of observations.	Barometer at noon.			
N.	483	759.76	millimetres,	= 29.91	Eng. in.
N.E.	378	759.89	...	= 29.91	...
E.	324	757.04	...	= 29.80	...
S.E.	231	754.60	...	= 29.70	...
S.	682	752.98	...	= 29.64	...
S.W.	727	752.38	...	= 29.62	...
W.	853	756.08	...	= 29.76	...
N.W.	335	758.67	...	= 29.86	...

We deduce the following *means* from all the observations at the fifteen European stations given by Kämtz—

Wind,	N.	Barometer,	756.45	millimetres,	= 29.78	Eng. in.
	N.E.	...	757.25	...	= 29.81	...
	E.	...	755.97	...	= 29.76	...
	S.E.	...	740.97	...	= 29.17	...
	S.	...	738.77	...	= 29.08	...
	S.W.	...	739.03	...	= 29.09	...
	W.	...	740.70	...	= 29.16	...
	N.W.	...	742.08	...	= 29.25	...

These indications afford a satisfactory proof of the fact that the mercury rises with N.E. and falls with S.W. winds. Taking into account certain anomalous results, and the geographical position of the localities, the following law has been derived: —When the wind blows from the north, and from the interior of continents, the mercury rises to the maximum; when it blows from the equator or the ocean, it reaches the minimum—mean oscillation. It is said, that at Calcutta the barometer is highest with north-westerly and northerly, and lowest with south-easterly, winds. This may be easily explained by the fact, that the elevating winds are colder than those which depress the mercury, and this arises from the physical conformation of the country. Changes in the barometer occur in

[1] Elémens de Physique.

unison throughout a large extent of our earth's surface. Excepting when under the influence of local tempests, these changes are almost always simultaneous over a couple of hundred miles.[1]

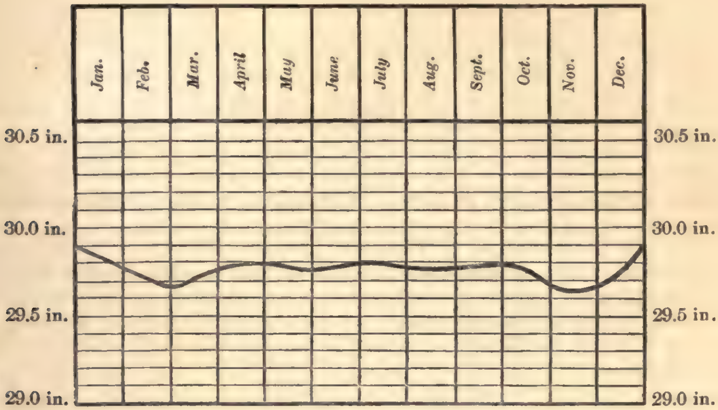
43. Sir John Leslie, in proposing a theory of barometric oscillations, premises, that storms or violent winds involve a vast extent of the earth's atmosphere, the influence of a West Indian hurricane being felt even here, at the distance of 5000 miles ; likewise that a current of air sweeping over the earth is deflected from its horizontal line by the globe's sphericity, or is acted upon by the opposing powers of gravitation and centrifugal force. This deflection, he believes, is attended by diminution of the pressure of the fluid, small at first but augmenting in its passage, and thus he explains the phenomenon. Whether correct or not, and it is opposed by Daniell,[2] it fails to account for all the phenomena ; thus, without admitting minor influences, it does not explain the upraising power of the N.E. wind. Whatever tends to increase or diminish the density of our atmosphere, elevates or depresses the barometer respectively, and temperature exerts this influence most powerfully. According to Meikle,[3] the peculiar actions of the N. E. wind in elevating, and of the westerly winds in depressing, the mercury, arise in the former case from the lessened centrifugal force of the wind, consequent upon the earth's rotatory motion, and thereby, its augmented gravitating force ; while in the latter, the westerly winds " conspiring with the diurnal motion, increase the centrifugal force and diminish the pressure." Marshall,[4] on the other hand, traces the elevating force of the N.E. wind to its low temperature, which may arise from its having blown over Norwegian snows in spring. The explanation of Mr Meikle is more generally applicable, and consequently the preferable hypothesis. We have already (33) referred to the views of Dove.

Subjoined is a table and diagram of the barometric curve in

[1] Vide Ephemerides Soc. Meteorologicæ Palatinæ—Mannhiem.
[2] Met. Essays.
[3] Jameson's Jour. 1827, vol. iv. p. 108, Dec. 1827. [4] Edin. Jour. of Science.

this country, from two hourly observations made night and day, Sundays excepted, at Greenwich Observatory during the years 1841–1845.

BAROMETRIC CURVE,—ENGLAND.



Mean Height of the Barometer at Greenwich Observatory, from observations of four years, made every second hour night and day, Sundays excepted.

Jan.	29.774 inches.	May	29.767 inches.	Sept.	29.807 inches.
Feb.	29.677 ...	June	29.798 ...	Oct.	29.660 ...
Mar.	29.759 ...	July	29.777 ...	Nov.	29.651 ...
April	29.806 ...	Aug.	29.772 ...	Dec.	29.874 ...

CHAPTER III.

"O thou that rollest above, round as the shield of my fathers! Whence are thy beams, O Sun! thy everlasting light? Thou comest forth, in thy awful beauty, and the stars hide themselves in the sky; the moon, cold and pale, sinks in the western wave. But thou thyself movest alone: who can be a companion of thy course! The oaks of the mountains fall: the mountains themselves decay with years; the ocean shrinks and grows again: the moon herself is lost in heaven; but thou art for ever the same; rejoicing in the brightness of thy course. When the world is dark with tempests; when thunder rolls, and lightning flies; thou lookest in thy beauty, from the clouds, and laughest at the storm. But to Ossian, thou lookest in vain; for he beholds thy beams no more; whether thy yellow hair flows on the eastern clouds, or thou tremblest at the gates of the west. But thou art perhaps like me, for a season, and thy years will have an end. 'Thou shalt sleep in thy clouds careless of the voice of morning,—Exult thou, O Sun, in the strength of thy youth!'"

OSSIAN,—*Carthon.*

44. The chief source of terrestrial heat is the sun, which among the heathen idolaters, especially among the ancient Persian followers of Zoroaster, under the symbol of fire,[1] and in the once magnificent kingdom of the Incas, received divine worship,—

---

[1] Herod. lib. i. cap. 131; Hyde—De Relig. Vet. Persarum. pp. 10-14.

....................." Glorious orb! the idol
Of early nature, and the vigorous race
Of undiseased mankind!... ....
Most glorious orb! that wert a worship, ere
The mystery of thy making was revealed!"
Manfred, Act iii. Sc. ii.

His beams are not only luminous but calorific,[1] and in addition, chemical or *actinic*,[2] and probably magnetic.[3] These rays may be refracted through diaphanous prisms and separately received. They possess the curious property of dissimilar refrangibility; and according to Seebeck[4] and Melloni, prisms of different substances produce remarkable changes in the calorific spectrum.[5] According to Forbes,[6] the thermal rays of the sun, before reaching our atmosphere, consist of two kinds, of which one is easily absorbable; the other cannot be absorbed, in its passage through our atmosphere; respectively as 4 to 1 of the whole number. But independent of luminous, thermal, actinic and magnetic (which however may be induced) rays, the sunbeam contains phosphorescent rays, under which certain chemical substances, *e. g.* sulphuret of lime,

[1] Scheele—On Air and Fire, Foster, 1780; The Abbé Rochon—Opusc. 1783; Sir W. Herschel—Ph. Tr. 1800; Sir H. Englefield in 1801—Jour. Roy. Inst. v. i. p. 203; Sir H. Davy; Sir John Leslie—Inq. into Nat. of Heat; Berard of Montpellier—Mém. d'Arcueil, tom. iii., Ann. de Chimie, 1813, tom. 85, p. 309, Ann. Phil. 1813; Professor Wünsch, in 1807—Mag. der Gesellsch; Dr Seebeck of Berlin—Ed. Jour. of Sc. ii. 358; Biot—Tr. de Phys. tom. iv. p. 600; Melloni—Annal. de Chimie, 1831, 388; Sir David Brewster; Professor Powell—Rep. Brit. Assoc. 1832, vol. i.

[2] Ritter of Jena—Nicholson's Sc. Jour. viii. 216; Beckman; Berthollet; Scheele—Tr. de l' Air, &c. 66; Davy—El. Chem. Philos.; Berard—An. Phil. ii. 1813; Wollaston—Ph. Tr. 1802; Wedgewood; Gay Lussac and Thenard; Senebier; Dr T. Young—Nat. Phil. v. ii. p. 647; Somerville—Ph. Tr. 1826, ii. 136; Christie—Ib. 1826, 1828; Sir J. Herschel—Lond. and Ed. Phil. Mag. 1832, 58; Daguerre; Fox Talbot; Arago; Hunt—Researches on Light; Saguez; Becquerel; Reiss and Möser—Brewster's Jour. v. ii. p. 225, Annal. de Ch. et de Phys. 1829, Poggend. Annal., Scient. Memoirs, vol. iii; Fizeau—Comptes Rendus, Nov. 7, 1842; Litterrat. der chemischen lichterstrahlen—Fortschritte der Physik, im Jahre 1845; Dargestellt von der Physikalischen Gesellschaft zu Berlin—Redigirt von Dr G. Karsten, 1847.

[3] Morichini in 1813—Ann. de Ch. et de Phys. iii; Somerville—Ph. Tr. 1826, ii. 132; Christie, Ib. 1826; Baumgartner of Vienna—Zeitscrift. i. 263; Barlocci; Zantedeschi of Pavia—Ed. Jour. of Sc. 1830, N. S. 5. 76; Ridolfi at Florence; Carpi at Rome; Reichenbach.

[4] Ed. Jour. of Sc. i. 358, Oct. 1824.

[5] Brewster—Brit. Assoc. Rep. ii. 294, 1832.

[6] Roy. Soc. May and June 1842.

spread on paper, glow when the violet ray of the solar spectrum is made to fall upon them. This result is not owing to the chemical rays present, for the latter may be transmitted through a medium which obstructs the passage of the phosphorescent beams. Others may exist though yet unknown or very obscure, *e. g.* the parathermic rays of Herschel, which, with distinguishing peculiarities, combine the actions of light and heat. The independent existence of these rays may be proved, by their separate effects when certain media are interposed. Thus a bright yellow solution, *e. g.* bichromate of potash, admits all the luminous, but obstructs the actinic rays; while the latter easily pass through the deep blue solution of ammonio-sulphate of copper, and scarcely a ray of light is transmitted. Melloni, with green glass and plates of alum, separated all the calorific from the luminous beams, and with black mica or obsidian, withheld the passage of the latter without imposing an obstacle to the transmission of the former.

45. The temperature of our atmosphere, or the amount of caloric[1] diffused in it, is constantly varying, being altered by an almost infinite number of circumstances; thus, altitude, latitude, longitude, horary and seasonal periods, the presence of aqueous meteors, winds, and the physical relations of the locality; even the aspect of the horizon, whether it is rugged or unbroken by lofty eminences, the chemical nature and colour of the soil, influence the result. As the sun advances to the meridian, we feel a corresponding increase of heat, which again declines soon after culmination. Were more required than our own sensations of warmth and cold, to prove the fact, the horary tables collected by indefatigable observers would abundantly testify.[2] Subject, however, to numerous fluctuations, we nevertheless observe, that there are two stated periods of the day when the temperature reaches a maximum and minimum. The warmest period is generally from two to

[1] *Caloric* properly means the active agent in producing heat. *Heat* the sensation of caloric.

[2] Brit. Scientific Serials, *passim;* Observ. of Roy. Soc. in Athen.; Tables of Kämtz,—Meteorologie; Lamont, at Munich, 1841,—Annal. de Météorologie; Beobachtungen zu Prag. 131; Brewster,—Ed. Roy. Soc. Trans. vol. x., North Brit. Rev. No. x.

three hours after the sun has passed the meridian, the difference depending upon season; the coldest is nearly an hour before sunrise. A mean may be conveniently obtained by recording the oscillations of the thermometer at suitable intervals, and thus the toils of hourly observation dispensed with. Thus the sum of the indications at 6 A.M., 2 and 10 P.M. or, as suggested by Schouw, at 7 A.M., noon, and 10 P.M, divided by 3, will give a near approximation to the diurnal temperature. From observations made by Professor Dewey[1] in North America, it would appear that the result obtained at the homonymous hours of 10 A.M and 10 P.M. afforded an approximation of 5–100ths of a degree to the true mean diurnal temperature. Though the maximum temperature occurs some time after the sun has culminated, we find that proximity to coasts accelerates the epoch; and in tropical regions the sea-breeze still farther modifies the result. The same has been found on mountain tops; nor is it at all remarkable: for, let it be observed, that in the plain, not only is the atmosphere warmed by direct solar rays, but by those radiated from the ground; upon the mountain top there will be a greater absorption of caloric and less radiation, more heat being abstracted by conduction there, than below, where the temperature of the earth is higher and more equally diffused. The temperature, then, upon those lofty spots, will depend chiefly upon the sun's direct calorific action, and as those rays are most powerful which pierce the thinnest atmosphere, *i. e.* when the sun is on the meridian, the hottest period of the day will be at, or very soon after, culmination. From hourly observations made at Leith Fort during the years 1824–1827, of which only two series, 1824 and 1825 have been published by Sir David Brewster in the Trans. Edin. Royal Society, we find that the hours of mean temperature, morning and evening, were respectively $9^{h.}\ 13^{m.}$ A.M. and $8^{h.}\ 26^{m.}$ P.M., 1824;—$9^{h.}\ 13^{m.}$ A.M. and $8^{h.}\ 28^{m.}$ P.M., 1825;—$9^{h.}\ 7^{m.}$ A.M. and $8^{h.}\ 27.25^{m.}$ P.M., 1826;—$9^{h.}\ 12^{m.}$ A.M. and $8^{h.}\ 23^{m.}$ P.M., 1827;—mean of all the observations, $9^{h.}\ 11.75^{m.}$ A.M. and $8^{h.}\ 26^{m}$ P.M. Although

[1] Ed. Phil. Jour. vol. vi. p. 352.

an advance on these hours is observed at Padua, still it is worthy of observation, that while the interval between the diurnal means, or *critical interval*, at the former station amounts to 11$^{h.}$ 14.75$^{m.}$, that at the latter is 11$^{h.}$ 11$^{m.}$; a similar constant has been noticed in Denmark, at Apenrade,[1] and elsewhere. Thus the critical interval at Philadelphia, is 11$^{h.}$ 20$^{m.}$; at Inverness, 11$^{h.}$ 13$^{m.}$; at Rothesay, 11$^{h.}$ 7$^{m.}$,—from an hourly register kept for twelve consecutive years by the late Robert Thom, Esq. of Ascog, and communicated to Sir David Brewster,[2] the mean temperature (47.°46 F.) occurring at 8$^{h.}$ 32$^{m.}$ A.M. and 7^{h} 39$^{m.}$ P.M.;—at Kingussie, 10$^{h.}$ 44$^{m.}$; at Belleville, 11$^{h.}$ 14$^{m.}$; at Tweedsmuir, 11$^{h.}$ 15$^{m.}$; at Plymouth, 11$^{h.}$; at Kandy, 11$^{h.}$; at Madras, 10$^{h.}$; at Colombo, 10$^{h.}$ 55$^{m.}$; at Trincomalee, 11$^{h.}$ 5$^{m.}$ From the Leith observations another law may be deduced, viz.—that the mean of two *homonymous* hours, or hours of same name before and after midday, differs from the mean annual temperature, on an average of 0.24° F.; the maximum difference being 0.421°, and the minimum, 0.059°. Referring to this interesting subject, Sir David Brewster[3] says,—"If we measure and represent by lines the mean temperature of every hour of the revolving year, we cannot recognise, in our own climate at least, any trace of a law which regulates the daily progression of heat. For weeks and months the hourly variations are of the most capricious and irregular character; the thermometer being sometimes stationary for a day, sometimes highest at midnight, and lowest at noon. When we combine, however, the 365 observations at each hour, by taking their mean, we find that these hourly means are the ordinates of a curve of beautiful regularity, each of the four branches of which do not differ much more than a ¼ of a degree of Fahrenheit from parabolas!"

46. Having obtained the mean daily temperature, that of the month is easily computed by arithmetical rule, the sum of the diurnal indications divided by the number of days giving the required quotient. And it is not a little remark-

[1] Schouw,—Beiträge zur vergleichenden klimatologie 1827.

[2] North Brit. Rev. No. x. vol. v. p. 499. [3] Ib. p. 455.

able to witness the steady result through a succession of years. As we have observed that in diurnal periods there are hours of maxima and minima, so in the year similar extremes are found. According to Kämtz, the maximum occurs on the 26th of July, and the minimum on the 14th of January; while the mean is upon the 24th of April and the 21st of October. M. Crahay,[1] from observations at Maestricht from 1818–33, gives the maximum upon the 19th July, and the minimum on the 22d of January. Bouvard[2] found the maximum at Paris to be upon the 15th July, and the minimum on the 14th of January. Arago,[3] from very extensive data obtained at the Paris Observatory between 1665–1823, found the day of greatest heat to oscillate irregularly in the months of July and August, while that of most intense cold usually fell about the middle of January. These results are subject to influences from winds and aqueous meteors continuing for a shorter or longer period.

47. Gay Lussac and Biot, during their aërial voyage from the Conservatoire des Arts, on the 23d August 1804, observed the thermometer to be 61.7° F. and the barometer 30.13 Eng. inches at the moment of ascent. When they had reached the altitude of 8600 Eng. feet, the thermometer stood at 56°.4 F.; at the height of 12,800 feet it fell to 51°, while at the Observatory it was 63°.5. The wind was blowing N N.W. during the voyage. On the 15th of September same year, Gay Lussac ascended, from the same place, a second time, *alone*, at 9$^{h.}$ 40$^{m.}$ A.M. The temperature was then 82° F. and the barometer 30.66 Eng. inches. At 12,125 Eng. feet the thermometer was so low as 47°.3, but began to rise as he ascended. At the height of 14,000 feet, it had risen to 50°.5 F.; the day was advancing, and the temperature over Paris considerably increased. At the elevation of 18,636 feet, the thermometer sunk to 32°.9 F., and at the great altitude of 22,912 feet above Paris, or 23,040 feet above the sea (equal to 1600 feet above Chimborazo, or more than 4.25 miles perpendicular al-

[1] Mém. de l'Acad. de Bruxelles, tom. x.

[2] Mém. de l' Inst. 1824.

[3] Annuaire du Bar. des Long. Paris, 1825.

titude[1]), the temperature was 14°.9 F. It was then $3^{h.}$ $11^{m.}$ P.M. and the wind S.E. The weight of atmosphere which Gay Lussac then sustained was only about a fifth of that borne at the surface of the earth.

48. The temperature falls, it has been shewn, as we ascend in a balloon, it decreases likewise with terrestrial altitudes. The absolute quantity of heat, however, is the same at every elevation ; and the true explanation of the coldness of the higher regions, is to be found in the increased capacity which the atmosphere acquires for caloric, by its rarefaction.[2] Our present data, which by the way, are still very scanty, lead to the conclusion, that the temperature on a mountain top is lower than at the same elevation over a plain. It has been observed too, by M. de Saussure, that the winter and summer means are less variable the higher we ascend ; this arises from the fact, that the depression is greater in summer than in winter in proportion to the elevation.

49. The calorific action of radiant heat upon the atmosphere is closely connected with the curious fact, that bodies which freely transmit heat without having their own temperature increased, when the rays are luminous, *i. e.* diathermic substances, absorb a portion of the heat when they are non-luminous ; consequently the light-giving rays darted to the earth radiate dark beams into space, which elevate the temperature of the air in proportion to its proximity to the ground. But it does not appear that they exercise an appreciable influence on the lofty regions of the atmosphere above the plains. Currents of air are constantly sweeping over the

[1] It may interest to know how much of the globe was visible at this great altitude. We know that the superficies of a segment of a sphere, is to the superficies of the whole sphere, as the versed sine of the segment, to the diameter of the sphere. Hence the following proportion :—

Diam. of earth : Height of balloon = superf. of earth : Field of vision ;

which expressed in numbers—allowing for the earth's diameter the mean of the equatorial and polar diameters, *i. e.* 7911.75 miles, and for the height of the balloon 23,040 feet, or $40.\dot{3}\dot{6}$ miles—gives,

$$7911.75 : 4.\dot{3}\dot{6} = 1 : \frac{1}{1813}.$$

The portion visible, then, was equal to the 1813th of the surface of our globe, or about 10,857 miles.

[2] Darwin—Ph. Tr. 1788. v. 78, p. 43.

land, and as heat lessens the specific gravity of air, these currents assume an upward course, till they meet with particles equally rarefied. The difference in temperature referred to, is due to these two forces—calorific radiation and atmospheric currents.

50. Saussure, with the view of ascertaining if the solar beams lost caloric in the higher regions of the atmosphere, instituted a series of experiments, from which he found that bodies freely exposed lost 14° at an altitude of 777 toises, but when completely defended they gained 1° by the thermometer. Thus, the higher we go the direct rays are more powerful, guarding against those radiated from the ground and surrounding bodies. Instruments have been ingeniously constructed for shewing the loss of caloric in the transmission of solar rays. For this purpose the *differential thermometer* was modified by Leslie, a *heliothermometer* invented by Saussure, an *actinometer* by Herschel, and two *pyrheliometers* by Pouillet.[1] By these it is found, that the rays which reach the ground are not above one-half of those which entered at the extreme limit of our atmosphere ; nevertheless the lower strata are the warmer, through the absorption of the dark calorific beams radiated from the earth.

51. In equatorial regions, according to Humboldt,[2] there is a decrease of 1° F. for an ascent of very nearly 344 feet, *i. e.* 1° R. for 121 toises. The mean of various observations in Europe gives 1° F. for an ascent of 296 feet. Much, however, depends upon the character of the elevation, whether it is above plains or seas, mountain ranges or solitary hills, and the season, as has been shewn by Guerin[3] at Ventoux, near Avignon, where, during summer, 1° Cent. corresponded to 156 metres, or 1° R. to 80 toises, and in winter, 1° Cent. to 195 metres, or 1° R. to 100 toises. Bravais has collected the results of aërostatic voyages made by Gay Lussac, Zeune and Jungius, Graham and Beaufoy, Sacharoff, and Clayton, from which we deduce the following average,—for an elevation of 201.61 metres, 1° Cent., *i. e.* for an altitude of 367.45

[1] Elém. de Phys. tom. ii. p. 528 ; Compt. Rend. tom. vii. p. 24. 1838.
[2] Observat. Astronomiques, 4to. i. 126.
[3] Annal. de Chimie, xlii. 428.

English feet, 1° F. But as the density of air decreases with altitude, although the specific caloric may be the same, we find that these numerical indications must be modified when applied to the higher regions of the atmosphere. To Atkinson[1] is due the following law, that equal decrements of heat correspond to increments of height in arithmetical progression.

52. Latitude exerts a powerful influence upon temperature, modified, however, by longitude, continental or insular position, altitude, mountains, woods, seas, lakes, and prevailing winds. These, in fact, determine *climate*, the modifications of which depend upon heat and moisture. Though highest at the equator, the temperature of our atmosphere is not lowest at the poles, nor does it decrease equally as we recede from the equinoctial line. The amplitude of the thermometric wave is greater upon a continental than in an insular locality. Thus, from the Leith observations referred to, and those made by Hansteen at Christiania,[2] in 1827, the difference between the mean temperatures of July and February equalled 19°.74 at the former, and 45°.40 at the latter place. Hence the peculiarly mild climates of insular positions; but as this subject belongs more particularly to physical geography, we dismiss it for the present.

53. Mount Ophir, in Sumatra, which is under the line, and rises above the sea 13,800 feet, has its lofty summit far below the limit of perpetual congelation. But were mountains to rise at the equator to the height of 15,000 feet, even there should we meet with constant snow. The theory of this is intimately connected with the laws of latent heat. As the earth radiates caloric to the surrounding atmosphere, the column of rarefied air ascends, increasing its capacity for caloric as its volume expands. The heat becomes inappreciable to the senses,—it is latent or insensible;—the air no longer imparts a genial warmth, and the temperature does not rise above that of ice. This limit of perennial snow is highest near the equator, decreasing as we approach the poles; its boundaries, too, are

[1] Mem. Astron. Society, vol. ii. [2] Ed. Jour. of Sc. vol. ix. p. 309.

most contracted within the tropics. "The limit of perpetual congelation," says the late Sir John Leslie, "forms a curve, which is nearly the same as the companion of the cycloid, bending gradually from the equator, reverting its inflexion at the latitude of 45°, and grazing the surface at the pole."[1] It may seem remarkable that the highest snow-line is not exactly at the equator, but about twenty degrees from that line. The explanation may be found in the length of the day in these latitudes, where, at the equator its duration is somewhat less than at the entrance to the tropics; consequently the vertical beams of an ardent sun contribute greater warmth there than immediately over the line.

54. As we enter the temperate regions, and advance to the frigid zones, we observe a much wider range between the snow-line of winter and that of summer; generally, too, this line is lowest on the northern side of the mountain. To this law, however, a remarkable exception is found on the loftiest mountains of our globe. The elevation of the snow-line, and the "resting" of the snow, are also influenced by geological structure; thus, on a granite base, snow lies longer, and the snow-line is lower, than on one of limestone, even in the same mountain group. On an isolated mountain it is higher than on a mountain chain situated in the same latitude. The warm winds from the plains account for this; and for a similar reason, an island mountain has its snow-line higher than a mountain on the Continent under the same parallel. The snow-line of the southern hemisphere is lower than that in the northern. Thus, according to Cook, it descends to the beach in the 59th parallel, and in the island of Georgia, in S. lat. 54°, to the level of the ocean.

55. According to Baron Humboldt, the snow-line of Mexico, in lat. 90° 20′ is 15,090 feet above the sea. On the side of Chimborazo it rises to 15,746 feet. The lofty summit of Mouna Kea in Hawaii, in lat. 19° 30′ nearly, is clad in snow, which gives to its well-defined outline a silvery brightness, visible "at fourteen leagues' distance."[2] In N. lat. 28° 15′ it is be-

[1] Ed. Cab. Lib.—Polar Seas, 32.

[2] King—Cook's Voyages.

lieved to be at 11,700 feet, about 250 feet above the Peak of Teneriffe; in lat. 37° 30′, on Etna, at 9000 feet; in lat. 42° 30′, in Asia, among the Caucasus, at 9000 feet; in lat. 46°, among the Alps, at 8220 feet; according to Hugi, the névé of the Alps is at a height of about 7800 feet. Among the Pyrenees, according to Bouvard, at from 1350–1400 toises, or a mean of 8892 English feet; but the Pic du Midi de Bigorre, which rises to a height of 1493 toises, or 9432 feet, is free of snow part of the year. At Edinburgh, were there a mountain sufficiently lofty, at 6000 feet; and in Iceland, in lat. 65°, at 2892 feet Farther north, in Lapland, in lat. 70°, where the winters are more rigorous, but the summers milder than in Iceland, according to Von Buch and Wahlenberg, the snow-line is 3517 English feet above the sea.[1] Humboldt[2] has given a valuable table of the limits of this line in both hemispheres, computed from measurements.

56. Upon volcanoes the snow-line is subject to occasional changes, depending upon the presence of internal fires. Thus, that of Mount Aconcagua, in S. lat. 32° 30′, to the north-east of Valparaiso, though higher than Chimborazo, has been seen without its snowy mantle; and in January 1803, the same was witnessed on Cotopaxi, the night before a dreadful eruption.

57. In lat. 30° 40′, at the temple of Kedar-nath, on the southern side of the Himmalehs, elevated 11,897 feet above Calcutta, or 12,000 above the sea, snow falls, but does not lie throughout the year. Captain Webb could not find a vestige of snow on the Nitee Ghaut, in Kemaoon at a height of 16,814 feet[3]. On this the northern side, the snow-line rises 17,000 feet above the sea. What a singular anomaly! A place in Asia having a snow-line 1200 feet higher than a mountain under the equator in

[1] Gilbert's Annalen der Physik, 1812, xli; Annals of Philos. iii. 347.

[2] Asie Centrale; Recherches sur les Chaines de Montagnes et la Climatologie comparée, par A. de Humboldt. 8vo. Paris, 1843, tom. iii. 359.

[3] On the 21st August 1818, on the crest of the Nitee Ghaut, in N. lat. 31°, at 3 P.M., Captain Webb found the average height of four barometers 16.27 inches, with a temperature of 47° F.; on the same day and hour, Colonel Hardwicke, at Dumdum, near Calcutta, about 50 feet above the sea, observed the barometer at 29.48 inches, and thermometer 84° F.

America! The village and temple of Milem among the Himmalehs, in lat. 30° 25′, are far below the range of perpetual congelation at an altitude of 11,790 feet, where even luxuriant crops are gathered. In the same European latitude, the snow-line descends several hundred feet below this altitude. At a similar height, on the 18th June 1818, Captain Webb was encamped amidst the most flourishing oak and arborescent rhododendrons. On the following day, on the crest of the Pilgointi Churhai pass, more than 12,700 feet above the sea, no snow was visible. Instead of white-capt mountains, a profusion of rich flowers met the eye; and even 1000 feet higher, the goat-herds lead their flocks. The pass of Oota Dhoora, which lies east of the Nitee Ghaut, and a day's march beyond Milem, was ascertained barometrically to be 17,780 feet high, and even there the snow lies only part of the year. The Bhotiya traders frequent this pass more than any other throughout the entire range. Gerard observes that he crossed beds of snow, when proceeding, in 1821, by the Chárang pass, 17,348 feet above the sea, to the valley of Nangalti. He also states, that the lofty mountains in the neighbourhood of Chárang, whose peaks tower to the giddy height of nearly 18,000 feet, are not covered with snow. On the right bank of the Tagla, at an elevation of 18,000 feet, snow was seen, but scanty; and those mountains which enclose the Tagla, rising between 19,000 and 20,000 feet are just tipped with it. He farther observes, "Zamsiri, a halting-place for travellers on the banks of the Shelti, is 15,600 feet above the sea,—a height equal to that of the passes through the outer range of the snowy mountains, and yet there is nothing to remind the traveller of the Himmalehs. Gently sloping hills and tranquil rivulets with banks of turf and pebbly beds, flocks of pigeons, and herds of deer, present the idea of a much lower elevation. But nature has adapted the vegetation to the country; for did it extend no higher than on the southern face of the Himmalehs, Tartary would be uninhabitable either by man or beast. On ascending the *southern* acclivity of the snowy range, the extreme height of cultivation is found to be 10,000 feet, and even there the crops are frequently cut green.

The highest habitation is 9500 feet ; 11,800 feet may be reckoned the upper limit of forests, and 12,000 feet that of bushes, although in a few sheltered situations dwarf-birches and small bushes are found almost at 13,000 feet. But if we go to the Baspa river, the highest village will be found at an elevation of 11,400 feet, cultivation reaching to the same altitude, and forests extending to 13,000 feet at least. Advancing farther, we find villages at the last-mentioned elevation, cultivation 600 feet higher, fine birches at 14,000 feet, and *tama* bushes, which furnish excellent fire-wood, at 17,000 feet. Eastward, according to the accounts of the Tartars, crops and bushes thrive at a still greater height." In 1823, from the crest of the Hangarang pass, whose height Gerard measured barometrically at 14,837 feet, this traveller beheld in front " a granitic range of most desolate aspect ; not a blade of vegetation visible, the snow itself only finding a resting-place at 19,000 feet." One longs to stand where this officer stood, and behold the sublime vista which he describes,—" Beyond it, through a break, were seen snowy mountains, pale with distance, appearing to rise out of the table-land on the banks of the Indus ; and from the angles of altitude which I observed, their pale outline, and the broad margin of the snow, they cannot be less elevated than 29,000 feet."

58. The snow-line among the Himmalehs, is thus shewn to be several thousand feet higher on the northern than upon the southern side, a fact of high value, as it proves the fallacy of theoretical calculations in this peculiar instance, which would have assigned for the snow-lines a position very different from that which it occupies. Doubtless the dry, serene, and transparent atmosphere of these lofty mountains, together with the radiation of heat from Thibet, are the cause of the anomaly described. Conclusive as the evidence appears, supported by the testimony of other travellers and Baron Humboldt,[1] that the snow-line is higher on the northern than upon the southern side of the Himmalehs, it is not a

[1] Ann. de Ch. et de Phys. tom. iii. 303 ; ib. xiv. 5–55 ; Asie Centrale, tom. iii. 281–327 ; Cosmos—Sabine, vol. i. p. 465 ; Calcutta Jour. of Nat. Hist. 1844, vol. iv., compared with Jour. of Asiat. Soc. of Bengal, 1840, vol. ix. pp. 575, 578, 500.

little singular, that the fact should be doubted by some and denied by others. It seems, however, beyond question, that the general opinion is correct, and though the peculiarity is singular, yet when we consider the cause, it is not remarkable.

59. We have at the beginning of this section stated that the solar beams contain, besides luminous and thermal, chemical or actinic rays. The two first are of variable intensity, as our senses prove, and this mutability is chiefly dependent on the earth's position in her orbit, and her diurnal revolution ; but the actinic rays suffer changes independent of these causes, and as yet not well understood. This has been proved by the *actinograph*, an instrument constructed for registering the amount of actinism in the solar beams. Mr Hunt found in his observations, that though the photographic papers employed were of uniform quality, he could not obtain a constant impression. Thus during the intensity of the heat and light of June and July 1846, the actinograph failed to reach the maximum. If that extreme be indicated by 100, then during these months the instrument ranged between 67 and 83. Practically the same truth was demonstrated, for it was with much difficulty that during these months photographic pictures could be obtained, notwithstanding an intense light and clear sky. Mr Bingham supposes this to have arisen from the condensation of moisture upon the plates, from the bromine solution employed. Probably it arose from the same unexplained cause which towards the equator produces a similar inconvenience. The cause we are yet unable to understand, but the fact is deeply interesting. May it not contain the germ of what, under the vague term of "atmospheric influence," exercised a force so powerfully destructive in this kingdom? It may be observed, that, during the same months, vegetation participated in the effects of unusual intensity of light and heat, by the development of leaves within the flowers. Results similar to those which follow the impact of solar rays, attend when photographic papers are placed in connexion with the negative wire of the electric apparatus.

CHAPTER IV.

60. Isothermal lines. 61. Illustrated. 62. Divide the globe into botanical regions. 63. Mean annual temperature. 64. Its remarkable steadiness. 65. Not materially changed since early ages. 66. Range of temperature, extreme heats. 67. Extreme colds. 68. Excessive cold may be borne with impunity. Extraordinary heats borne without injury. 70. Effect of intense cold on sound. 71. Provision made by the Esquimaux for spending their long winters; effect of cold and want of light upon human race. 72. Dangers escaped by a scientific party. 73. Physiological effects of great cold. 74. Antiseptic property of intense cold. 75. Poles of maximum cold. 76. Their connection with the magnetic poles. 77. Hypotheses. 78. Isogeothermal, isotheral, and isochimenal lines. 79. Formulæ for computing mean temperatures objectionable. 80. Influence of ocean upon temperature. 81. Influence of continents upon temperature. 82. Historical records of intense frosts. 83. Temperature of Southern Hemisphere. 84. Difference explained. 85. Temperature of space. 86. Whence its source.

60. As we recede from the equator, the extremes of annual temperature increase. The mean temperature of various latitudes attracted the attention of Baron Humboldt,[1] and with the view of tabulating the results, so that they might be presented in a tangible form, he constructed his Isothermal lines (ἴσος equal, and θερμος heat), or lines passing through places possessing the same mean annual temperature. This renowned philosopher detected a considerable difference in temperature between the old and new continents under the same parallels. Thus, at lat. 30°, the temperature in the old continent is 70°.52, while in the new continent it falls to 66°.9. Again, in lat. 40°, it is 63°.14 in the former, and 54°.5 in the latter; in lat. 50°, it equals 50°.9 in the one, and 37°.9 in the other;

[1] Mém. d' Arcueil, tom. iii. p. 462; Fragments Asiatiques, tom. ii. p. 398; Ed. Phil. Jour. vols. iii. iv. and v., 1820, 1821.

in lat. 60°, it falls to 40°.6 in the old world, and to 23°.7 in America.

61. The maximum isothermal line crosses the equator near to Singapore, in N. lat. 1° 23′, and E. long. 103° 52′, passing through Socotra in N. lat. 12° 40′, and E. long. 54° 20′, and Kouka in Central Africa, in N. lat. 13°, and E. long. 14° 10′; it dips towards the equinoctial line in W. long. 18°, within 2°, when it reascends, and 12° to the north passes South America; it now rapidly falls to the 3d parallel of N. lat., and in W. long. 150° crosses the equator, descending 7° to the south, when it again mounts, and gradually reaches the starting point. Under the tropics, the isothermal lines run nearly parallel to the equator across the Atlantic Ocean. In the higher parallels, they bend southerly towards the new continent; reaching America, they again assume a direction nearly parallel, till they cross the Rocky Mountains, where they receive a northerly inflection.

The isothermal line of 77° F. appears in Africa about the mouth of the Senegal, between 18°–19° N. lat., passes north of the Red Sea and the Persian Gulf, in lat. 28° 15′; descends towards Manilla, in lat. 14° 36′, entering the new continent near Acupulco, passing Vera Cruz and Havannah on the north. That of 68° F. passes between Madeira and Teneriffe, ascending towards Tunis and Algiers, coasts the African continent, passing between Cairo and Candia; it leaves Asia, having gone north of Lassa, and enters America in California, in lat. 28°–29°; it appears in South Carolina in lat. 32°, and leaves Bermudas in lat. 32° 20′.

The isothermal line of 59° F. passes Lisbon in lat. 38° 43′, thence runs between Florence and Rome in lat. 43°, and enters Asia in the south of Corea, leaving it in Japan in lat. 38° 58′ at Fort Savern. That of 54° F. passes through France in lat. 45° 46′ and long. 37′ east, approaches Pekin in lat. 39° 54′ and long. 116° 27′, and appears near the mouth of the Columbia River in lat. 44° 40′ and W. long. 104°. That of 50° F. passes through lat. 51° near to London and in the Netherlands; in Asia it dips to the 40th parallel, and is found in lat. 42°.5 near Boston in the United States; in Ireland it

rises to Dublin in lat. 53° 21°. That of 41° F. is found north of the Feroe Isles, rises in Norway to lat. 63° 26′, descends north of Stockholm to the south of Kasán and Moscow ; it is met with in Asia among the Kurile mountains ; enters America north of New Archangel, falling to Lake Michigan, and leaves that continent south of Newfoundland. The isothermal line of 32° F. touches the North Cape in Norway, in lat. 71° 10′, and dips, passing Labrador in lat. 54°, having crossed north of Kasán, in lat. 55° 8′. That of 5° F. runs south of Melville Island, by Port Elizabeth, in lat. 65° 59′, and rises north of Igloolik in lat. 69° 20′.

62. The isothermal lines, whose temperatures are respectively 78°, 68°, 59°, 50°, 41°, and 32° F., may be said to divide each hemisphere into seven separate zones having distinct climates, and characterised by peculiarities in the arborescent *flora* of each, *i. e.* in each of these regions, the plants flourishing *luxuriantly* are, with few exceptions, *sui generis.* Besides the influence of mean annual temperature in modifying the *habitat* of organic life, we must not forget the superior forces of extreme seasonal temperatures. In other words, not only do the isothermal, but the isochimenal and isotheral lines (78°) divide our globe into zones, characterised by their living structures. The same may be observed upon lofty mountains, particularly those which are isolated.[1] Between the equator and the isothermal line of 78°, which runs nearly parallel with the 20th degree of latitude, we find the spices grow, arborescent ferns, and wide-spreading palms ; it is the peculiar region of the *monocotyledones* of Jussieu. Between that and the line of 68°, which in Europe recedes to the 37th parallel, and dips in Persia and America to 31°, we find the coffee-tree, sugar-cane, and citron. The next region extends to the isothermal line of 59°, and there we find the northern confines of the orange, olive, and fig. The fourth is the peculiar *habitat* of the wine-grape. The fifth contains the northern limits of the oak, which in Norway are found in lat. 63°, but in Russia not beyond 58°, and in Asia still lower ; it includes

[1] Humboldt in Trop. America,—Géographie des Plantes Equinoxiales ; Schouw of Copenhagen, in Europe,—Phyto-géographie ; Wahlenberg in the Arctic Regions.

several *cerealia*, and wheat still ripens in perfection. In the sixth, which extends between the isothermal lines of 41° and 32°, grow firs, pines, and birches; it stretches north to lat. 71° in Europe, to the Arctic circle in Asia, and dips to 57° 8′ on the eastern shores of America. In the seventh, or the zone beyond the freezing-point of water, we meet with brushwood, mosses, lichens, and fungi, the *cellulares* of Decandolle. Schouw[1] has studied particularly the botanical geography of Europe, which he divides into four chief regions,—that of trees whose foliage is evergreen; that of the chestnut and oak; that of the oak and the beech; and that of the pine and the birch. The globe he divides into twenty-two regions. Even in the human race we perceive striking peculiarities.[2] Those regions might likewise be characterised by their *fauna*, and in the plumage of the feathered tribe there are as striking peculiarities.

63. At the equator the *mean* annual temperature is 27.5° C., or 81.5° F. in America.[3] In Africa it rises somewhat higher, probably to 84° F., and this is accounted for by the absence of vegetation. At Melville Island it equals —1°.6 F. Thus the difference between the maximum and minimum mean temperatures on our globe amounts to about 86° F. Mahlman,[4] has constructed a valuable and very full table of the mean annual temperatures of more than 300 places. From this table we select the following observations:—Maracaybo in Columbia, =84°.2 F.; at Sincapore, an island south of Malacca, remarkable for the singularly equable mean temperature of each month,[5] =79°.7; Calcutta, =78° 4′; Veracruz, =77°; Quito, at an altitude of 9560 feet, and at Nice on the level of the sea, =60°.1; at Rome, =59°.7; at Santa Fé de Bogota, 59°; at Madrid, elevated 2175 feet, =57°.6; at Paris, =51°.4; at London, =50°.7; at Vienna, =50°.2; at Cheltenham, = 49°.5; at Dublin, =49°.1; at Edinburgh, =47°.5; at Kendal, =46°.9; at Stromness in the Orkney Islands, =46°.4; at Mon-

[1] Europa, Physisch. Geog. Schilderung; Phyto-géographie.

[2] Prichard's History of Man, &c.

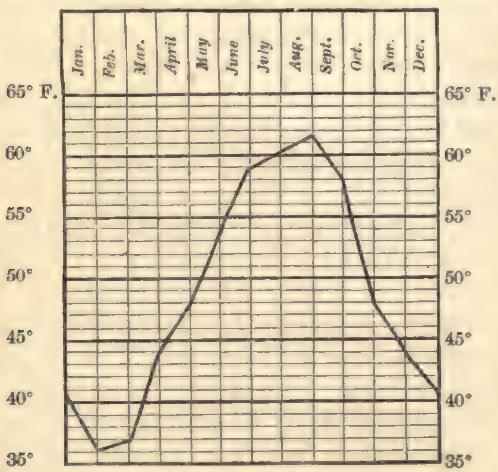
[3] Humboldt; according to Berghaus of Berlin, author of the Physical Atlas, it is 82°.25 F.

[4] Asie Centr. tom. iii.

[5] Malcom—Trav. South-east. Asia.

treal, $=43°.7$; at Abo, $=40°.3$; at Kazan, $=36°$; and Eyofiord, Iceland, $=32°$ F. It will be observed, that though these results gradually decrease, they do not follow a direct increase of latitude. The mean temperature of 1846 observed at Edinburgh was 49°.5, which was 3°.25 higher than that of 1845. The range of the thermometer equalled 68°, viz., from 16° to 84° F. in shade. The mean of June was 7° above the same month in 1845 ; and that of July, August, and September exceeded the mean of the corresponding months of the previous year, 4° ; but that of December 1846, fell 4° below that of December 1845,—Dr Stark. In our latitude, the mean temperature of the year approximates that of the months of April and October. We subjoin a diagram of the mean monthly temperature of England, from observations made at Greenwich, during a period of four years, taken every second hour, night and day, Sundays excepted.

MEAN TEMPERATURE at GREENWICH OBSERVATORY, from Observations of four years, made every second hour, night and day, Sundays excepted.



Jan. 36°.4 F.	Apr. 47°.8 F.	July 60°.1 F.	Oct. 48° F.
Feb. 36°.8	May 53°.8	Aug. 61°.5	Nov. 43°.2
Mar. 43°.9	June 59°.1	Sept. 57°.7	Dec. 40°.5

64. A remarkable steadiness of mean annual temperature has been observed in the same locality, regardless of the con-

stant and seemingly irregular oscillations of the thermometer. The late Professor Daniell[1] has remarked that the average temperature of London remains with very slight variation at 50°.4 F. In 1788, 1796, and 1813–14, memorable for the intensity of the cold, the mean temperature was 50°.6, 50°.1, and 49° F. respectively. The years 1808 and 1846, remarkable for great summer heats, averaged 50°.5, and 51°.67 respectively.

65. That human agency may be subservient to producing considerable local changes in the temperature of the seasons, by draining marshy countries, cutting down forests, and bringing the soil under cultivation, cannot be doubted; but it has been shewn by Arago,[2] in a series of collected observations, extending back to a century before the birth of Christ, that, upon the whole, there is no material alteration upon the temperature of the seasons. Schouw[3] has demonstrated the same; and, by a happy accident which has restored Raineri's early Florentine registers, Signor Libri has shewn that the climate of northern Italy is now the same as it was in the days of Galileo.

66. In India the range of the thermometer is very great, extending from nearly zero before sunrise, to 130° F. at noon. The highest temperature is met with near the level of the sea in the Circars, and in the Great Western Desert. The thermometer is recorded to have stood in 1799 in the northern Circars, at midnight, at 108°, and at 8 A.M. at 112° F. A land wind had blown for a fortnight. In the Arabian desert the temperature of the night is remarkably sultry,[4] being generally 100°, rising towards morning, and during the day being much higher. In the "suffocating Pandemonium" of the great salt lake of Bahr Assál, in lat. 11° 37′ 30″ N., and E. long. 42° 33′ 6″, 570 feet below the sea level, Major Harris,[5] found the thermometer at 126° F. though covered up, and this suffocating heat continued throughout the day of his encampment. The physical features of the locality explain most satisfactorily

[1] Meteorology. [2] Annuaire pour 1825, 1834. [3] Ed. Jour. of Sc. viii. 311.
[4] Fraser's Jour. into Korassan, ch. i. climate of Omán.
[5] Highlands of Ethiopia, vol. i.

this extraordinary heat, for this "unventilated and diabolical hollow" is engulfed between lofty and rugged mountains, being reached by a narrow defile. The station immediately adjoining is 1700 feet above the level of the sea, and consequently 2270 feet higher than the lake. It has been observed[1] that in Lower Egypt, during the hot season, the thermometer in the shade ranges at noon from 90°–100°; in Upper Egypt, from 100°–110°; in Nubia, from 110°–120°, and even, though rarely, to 130°; exposed to sand and sun it has risen even to 150° F. in the latter country. Near the Euphrates, in the desert, Griffiths[2] observed the heat during land-winds amount to 132° in shade, and even 156° in the sun. Buckingham[3] records having seen the thermometer in the shade at 126° two hours after noon; and Burckhardt[4] at 117°.5 at Esné in Upper Egypt. According to Schouw, the extreme temperatures of Palermo, Rome, Turin, and Nice, are 103°.5, 100°.4, 98°.4, and 92°.1 F. respectively; Arago, gives 101°.1 for Paris; Strnadt, 95°.7 for Prague; Stritter, 89°.6 for Moscow; Parry, 60°.1 for Melville Island. But these are *land* observations. Arago[5] has shewn that over the ocean, the maximum temperature is 30° Cent. or 86° F. It is between the 40th and 45th parallels in both continents, that we meet with the most rapid decrease of temperature.

67. Observation leads us to believe that about 80° N. lat. the most intense cold in this hemisphere occurs. Pallas observed the temperature at —40° F. in lat. 58°, in Siberia. Haüy says, that it is recorded[6] that a temperature of —57° had been once registered in Russia. Gmelin the elder, who between 1733–43 explored Siberia, records the temperature at 8 A.M. on the 10th February 1738, at the foot of Kiringa, at —72° F.; at the same place, in December, he experienced it even as low as —90° and —120° F.[7] Cochrane[8] found the thermometer at —46° F. in November, at Yakutsk on the Lena. Sir W. E.

[1] Lane's Englishwoman in Egypt, let. vi.
[2] Trav. in Arabia, p. 384.
[3] Trav. in Mesopotamia.
[4] Travels.
[5] Annuaire pour 1815, p. 186.
[6] Trans. Acad. St Petersb.
[7] Encyc. Brit. 7th ed. vol. xx. p. 325.
[8] Pedest. Tour through Russia, &c. vol. ii. p. 108.

Parry found it so low as —55°F. at Melville Island, on Tuesday the 15th February 1820, in lat. 74°47′15″, and W. long. 110°48′30″. It was then 6 A.M., and the barometer =29.72 inches; a slight breeze springing up, the thermometer rose to —50°F. On the afternoon of the preceding day, it had sunk to —54°F. In lat. 65°N. Sir John Franklin experienced cold even more intense, the spirit having fallen to 57°F.[1] Sir John Ross witnessed the thermometer even lower still by 3°; and Captain Back,[2] at Fort Reliance, on 17th January 1834, recorded it at —70°; with a large fire of wood in a small room, he could not get the temperature above —12°. Stritter records a minimum of —34°.6 at Moscow; Arago, —9°.2 at Paris; Schouw, 14°.2 at Nice, and 22°.6 at Rome; Neibuhr, 48°.4 at Cairo; at Madras, 63°.1, and at Pondicherry, 70°.9 F. Dr Wilson,[3] on January 14. 1780, at 6 A.M. observed the thermometer at Glasgow at —14°, or 46° below the freezing-point of water; on the 6th February 1823, at 1.5 A.M., it fell to —15°F., at the seat of J. P. Grant, Esq. of Rothiemurchus in Inverness-shire.[4]

68. Sir W. Ed. Parry remarks, that such extremely low temperatures can be borne without inconvenience when the air is calm, but upon the slightest wind arising, its effects are manifested in a smarting sensation and headache. Its influence in producing mental torpor was likewise observed. Captain Lyon,[5] who accompanied Captain Parry, thus describes his own feelings from the cold at Iglŏolik, in N. lat. 69°20′42″, and W. long. 81°40′12″, their second winters quarters, where, he observes, the winter was more severe than the preceding, and the mean temperature of December below that at Melville Island. Captain Lyon premises, that to him the change from the hottest (African) to the coldest climate on our globe in a very short period, rendered his case remarkable. "At our first quarters," says he, "my clothing, with the exception of a thicker jacket, was the same as I had worn during the summer. I never exceeded one pair of thin worsted stock-

[1] Nar. 3d ed. vol. ii. p. 27.
[2] Beechy and Back—Trav. Arct. Reg. p. 631.
[3] Ph. Tr. 1780, p. 451.
[4] Ed. Phil. Jour. vol. viii. p. 396.
[5] Priv. Jour. p. 304.

ings, neither did I find it requisite, unless the weather was windy, to wear either a great-coat or comforter when walking out. There were two or three others equally insensible to the cold as myself; but the change of climate had an effect on me which, I believe, was not experienced by the rest, and which was, that the hair from my head regularly *moulted*, if I may be excused the expression, and was renewed two or three times; even in the summer following, and this second winter, the process still continued, although in a slighter degree. My health was all this time better than I had ever enjoyed for so long a period. But we all now felt the necessity of putting on additional clothing; both while below, and when walking out, coldness in the feet was, I believe, the most general complaint. . . . . Our stove-funnels collected a quantity of ice within them, notwithstanding fires kept up night and day, so that it was frequently requisite to take them down, in order to break and melt out the ice, as it collected in the same form as the pulp of a cocoa-nut lies within the shell."

69. Having thus noticed the extremes of cold to which the human body has been subjected without injury, it may be interesting to place in opposition, though they cannot be compared, the extremes of heat which have been borne with impunity.[1] Sir Joseph Banks, Dr Solander, and Sir Charles Blagden, entered a chamber, the temperature of which was 198° F., and remained there ten minutes. Banks went in alone when it was heated to 211°, and Dr Solander, at that of 210°, unaccompanied by his friend. Blagden exposed himself to a heat of 261° F., walking about the apartment, where he remained eight minutes. Sir Francis Chantrey has exposed himself to a temperature of even 320° F. in his drying furnace.

70. It was observed in the polar regions during the intense colds described, that sound was heard at great distances; conversation could be carried on a mile off, and louder tones were perceived over a wider space. "These," says Sir W. E.

[1] Ph. Tr.—Exper. of Fordyce in 1775.

Parry, "served now and then to break the silence which reigned around us ; a silence far different from that peaceful composure which characterises the landscape of a cultivated country ; it was the death-like stillness of the most dreary desolation, and the total absence of animated existence."

71. The rude Esquimaux, in anticipation of the cold of these inhospitable climes, before the approach of the dreary polar night, immure themselves, clad in skins, within their wretched snow-huts, and doze away the tedious hours. Their miserable abodes they carefully stop against the piercing cold, and if by accident or design there should be made an aperture to admit the air, the internal moisture immediately falls in a shower of snow. The long exposure to cold and privation of solar light during so many months, gives to the inhabitants of polar regions striking physiological distinctions. We find the Laplander, the Greenlander, the Esquimaux, the Samoïed, and the Ostiaks, a stunted race, feeble both in body and in mind. Diseases there are rarely of the sthenic character, but assume the asthenic type. The Fuegians of the southern hemisphere, are described as "the most abject and miserable race of human beings."[1]

72. Having mentioned the effects of intense cold in the Arctic Regions, we would give at length an interesting account of the sufferings of a scientific expedition at the southern extremity of the American continent. Sir Joseph Banks, Dr Solander, and party, had in 1769, ascended the mountains of Terra-del-Fuego, on a botanizing and exploring excursion, when the effects of severe cold in an attenuated atmosphere upon their wearied bodies, was painfully experienced. "Dr Solander, who had more than once crossed the mountains which divide Sweden from Norway, well knew that extreme cold, especially when joined with fatigue, produces a torpor and sleepiness that are almost irresistible. He therefore conjured the company to keep moving, whatever pain it might cost them, and whatever relief they might be promised by an inclination to rest. 'Whoever sits down,' said he, 'will sleep : and whoever sleeps will wake no more.' Thus at once, ad-

[1] Sir James Clark Ross—Voy. of Discov. 1839–43. Lond. 1847.

monished and alarmed, they set forward; but while they were still upon the naked rock, and before they had got among the bushes, the cold became suddenly so intense as to produce the effects that had been most dreaded. Dr Solander himself was the first who felt the inclination, against which he had warned others, irresistible; and insisted upon being suffered to lie down. Mr Banks entreated and remonstrated in vain; down he lay upon the ground, although it was covered with snow, and it was with great difficulty that his friends kept him from sleeping. Richmond also, one of the black servants, began to linger, having suffered from the cold in the same manner as the Doctor. Mr Banks, therefore, sent five of the company, among whom was Mr Buchan, forward to get a fire ready at the first convenient place they could find; and himself, with four others, remained with the Doctor and Richmond, whom, partly by persuasion and entreaty, and partly by force, they brought on; but when they had got through the greatest part of the birch and swamp, they both declared they could go no farther. Mr Banks again had recourse to entreaty and expostulation, but they produced no effect. When Richmond was told, that if he did not go on he would in a short time be frozen to death, he answered, that he desired nothing but to lie down and die. The Doctor did not so explicitly renounce his life; he said, he was willing to go on, but that he must first take some sleep, though he had before told the company, to sleep was to perish. Mr Banks and the rest found it was impossible to carry them; and there being no remedy, they were both suffered to sit down, being partly supported by the bushes; and in a few minutes they fell into a profound sleep. Soon after, some of the people who had been sent forward, returned with the welcome news that a fire was kindled about a quarter of a mile farther on the way. Mr Banks then endeavoured to awake Dr Solander, and happily succeeded. But though he had not slept five minutes, he had almost lost the use of his limbs, and the muscles were so shrunk, that the shoes fell from his feet; he consented to go forward with such assistance as could be given him, but

no attempts to relieve poor Richmond were successful."[1] When accompanied by humidity the danger is very great, as has been shown by Dr Currie in the case of a shipwrecked crew. Two out of the three lost, were constantly exposed to a piercing wind with sleet, and had their bodies frequently submerged; they survived only four and seven hours respectively. The third who died, was a weakly man; but of the eleven saved, all had been *completely* immersed for twenty-three hours.

73. The reader need not be reminded of the melancholy disaster which befell the army of Napoleon in the famous Russian Campaign, from this cause.[2] The nervous system became first affected, and soon thereafter the heart ceased to perform its functions. The retreating soldiery reeled like drunken men, the sight became obscure, somnolence deepening into stupor followed, on and on they staggered, till they fell to rise no more! Upon the 2d September 1847, two unfortunate gentlemen travelling in the Highlands were found dead near the foot of Ben-Nevis. It had been a very stormy night the evening before, and fatigued they sat down together, when, emptying a flask of corn-spirit, they are supposed to have fallen asleep:—it was the sleep of death.[3] It is almost unnecessary to observe, that exposure to great cold, especially when the nervous energies are low, often results in mortification of the limbs. At other times, paralysis follows without loss of vitality. Of this a remarkable instance occurred in the person of the Abbé Scarron,—"the unworthy valetudinarian to the Queen" of France. In his buffoonery, this wretched wit had sported as a savage in the carnival. In this state of dissipation he experienced prolonged exposure to cold and dampness, which deprived him of the use of his

[1] Cook's First Voy.; Maupertuis in Tornea, and description of Beaupré. See too, on the cause of death by cold, Quelmalz—Prog. quo Frig. Acrioris in corp. effectus expedit, &c., in Halleri Disp. Med. 1758, tom. vi.; Rosen—Anat. p. 142; Kellie—Med. Chir. Tr. Ed. i. 84; &c.

[2] Vide Quint. Curt. lib. vii. cap. v.; Parrat et Martin,—Actes de la Soc. de Santé de Lyon, i. 300.

[3] Letter of A. Fraser, Esq., Sheriff-substitute of Inverness, to the Lord Mayor; Fort-William, Sept. 3. 1847,—Public prints.

extremities. His mental powers were unaffected; he afterwards married Frances D'Aubigné, subsequently Mad. de Maintenon, and wife of Louis XIV. Apoplexy, particularly in the aged, may result from the same cause, and those other diseases which arise from depressed nervous power and increased vascular action in the internal organs, resulting from diminished circulation on the surface of the body.[1]

74. The antiseptic property of cold is well shewn in those inhospitable regions within a few degrees of the poles. The stores of Captain Parry, saved from the Fury, in the Arctic expedition of 1824–25, were found by Sir John Ross in a very perfect state upon the spot where they had been left, though the ship had entirely disappeared,—a remarkable providence, whereby the lives of those who had embarked in the latter enterprise were saved. It is recorded by M. Bleau[2] that the bodies of seven Dutch seamen, who perished in Spitzbergen in 1635, were found twenty years afterwards in a perfect state, not having suffered the smallest putrefaction. The body of Prince Menzikoff, buried at Beresov in Siberia in 1729, recently disinterred, was found in a state of perfect conservation, skin, mustachios, and whole body.[3] About the year 1770 an animal resembling a rhinoceros was found in good preservation in a block of ice on the banks of the Wilujii in Siberia. It had hair upon parts which are leathery in the existing species. Some years later an elephant, partly covered with hair, was found by the side of the Alaseia, which flows into the icy sea beyond the Indigirsha. About the beginning of the present century, another elephant was disembedded from a mass of ice at the mouth of the Lena in lat. 72° and long. 128°. So preserved was the flesh of this antediluvian mammoth, that it was devoured by the natives, the bears, the wolves, and their dogs. It had woolly hair or fur upon several parts of the body, shewing that it had lived in a climate considerably colder than that of India or Africa. These animals

[1] Cullen, Fothergill, Marcard, Wepfer, Zacutus, Walther, &c.

[2] Atlas Historique; Scoresby,—Arctic Regions, vol. i. p. 344.

[3] Murchison,—Jameson's Journ. vol. xl. p. 348, note. Erman—Reise um die Erde, &c.

must have died a violent death and been frozen immediately thereafter, before decomposition had begun. The tusks of the Lena elephant were nearly ten feet long, and circular. The fisherman who, five years before, had made the discovery, possessed himself of these enormous tusks, and, ignorant of their value, sold them for fifty rubles. They were repurchased by M. Adams of St Petersburg, and deposited in the Museum of the Academy there.[1] Pallas, so early as 1769, demonstrated that the elephant, rhinoceros, and hippopotamus, were once the inhabitants of Siberia.[2]

75. Sir D. Brewster has shewn that the mean temperature of the North Pole is not under 5° F., probably as high as 17°, supposing that the ocean extends so far; but Arago estimates the temperature much lower,[3] on the probability that the continent extends to the pole. Brewster observed that, in the 80th parallel of latitude, and in 100° W. long. in the polar seas, and 95° E. long. near to the N.E. Cape in Asia, the isothermal lines indicate two poles of greatest cold. These have been termed the Transatlantic or Canadian, and the Asiatic or Siberian Poles of maximum cold. Berghaus[4] places the American pole in N. lat. 78°, and W. long. 89° 29′ 45″; and the Asiatic, in N. lat. 79° 30′, and E. long. 120° 20′ 15″; to the former he assigns a mean temperature of —3°.46 F., and to the latter that of 1° F.

76. When Sir David Brewster in 1820 gave to the scientific world the result of this remarkable discovery of two poles of maximum cold, on either side the pole of revolution, in the northern hemisphere, he drew the attention of *Savans* to the striking connection between these and the magnetic poles.[5] "Their local coincidence," he observes,[6] "is sufficiently re-

[1] Adams,—Journ. du Nord. 1805; Brougham's Analytical View of Cuvier's Ossemens Fossiles; Lyell,—Geol. vol. i. p. 99; Professor Owen,—Brit. Foss. Mammal. p. 261; Murchison's Geol. of Russia, p. 500; Menageries, Lond. 1831, vol. ii. p. 365, &c.

[2] Mem. on Foss. Bones of Siberia, in Mem. of Imper. Acad. of St Petersb.,—Novi Commentarii, 13, 18; Phil. Trans. 1776.

[3] Annuaire pour 1825, p. 186.

[4] Physical Atlas.

[5] It was in 1831 that Sir J. C. Ross unfurled the British flag *upon* the N. magnetic pole.

[6] Ed. Roy. Soc. Tr. 1820; Pog. Annalen. i. 323.

markable, and it would be to overstep the limits of philosophical caution to maintain that they have no other connection than that of accidental locality." This connection of the locality of these poles of cold with those of magnetism, and the coincidence of the isothermal lines around the poles of revolution with the isodynamic magnetic curves, is admitted by Erman,[1] from observations at Jakousk.

77. "How far," in the words of the same philosopher, "the general form and position of the continents and seas of the northern hemisphere may disturb the natural parallelism of the isothermal lines to the equator,—to what extent the current through Behring's Strait, transporting the waters of warmer climates across the polar seas, may produce a warm meridian in the direction of its motion, and throw the coldest points of the globe to a distance from the pole,—whether or not the magnetic, or galvanic, or chemical poles of the globe (as the important discoveries of M. Oersted[2] entitle us to call them), may have their operations accompanied with the production of cold, one of the most ordinary effects of chemical action,—or whether the great metallic mass which crosses the globe, and on which its magnetic phenomena have been supposed to depend, may not occasion a greater radiation of heat from those points where it develops its magnetic influence, are a few points which we may attempt to discuss when the progress of science has accumulated a greater number of facts, and made us better acquainted with the superficial condition as well as the internal organization of the globe."[3] Humboldt[4] views the inflexion of these isothermal lines as arising from the physical aspect of continents,—form, magnitude, and height,—in relation to polar ice.

78. The isothermal lines do not coincide with lines passing through places where the mean temperature of the earth is the same, and called *isogeothermal* lines,[5] but run nearly pa-

[1] Reise um die Erde. tom. ii. 250.

[2] It was in 1819 that Oersted made the fine discovery of electro-magnetism,—An. Phil. xvi. 273.

[3] Ed. Tr. 1820. Brewster.

[4] Asie Cent. tom. iii.

[5] Kupffer,—Voy. au Mont. Elbroutz, 4to.

rallel to them, describing ordinates and abscissæ peculiarly their own.

Two other series of lines are known to the meteorologist. These are the *isotheral* and *isochimenal* lines,—the former corresponding with the lines of mean summer temperature, and the latter with those of mean winter temperature. Receding from the equator these seasonal lines diverge from one another, in proportion to the difference between the summer and winter temperature of the place. Their deflections are sometimes great, especially in the interior of continents, where, in consequence of physical peculiarities, the difference between the extremes of heat and cold is considerable.

In Europe, we find the *isochimenal line* corresponding to — 5°C. or 23°F. running through Iceland ; gently curving, it reaches the north of Norway, where it inclines southward in the direction of the mountains, and crosses the Baltic about the Gulf of Finland ; pursuing its path across the continent, it enters Asia to the south of the Sea of Aral. That of 5°C. or 41°F. is met with in Ireland ; it is traced in the south-west of England, and appears in France near to Nantes ; it crosses the north of Italy, and passing through Turkey, is found in the southern part of the Caspian Sea. That of 15°C. or 59°F. merely touches Europe in its south-western corner, and entering Africa it passes through Barbary, approaching the Mediterranean at Tripoli, and appears in Asia to the north of the Persian Gulf. In the European continent, the *isotheral line* of 20°C. or 68°F. is found in the Bay of Biscay, and enters France south of Nantes ; it crosses that country, and is met with almost equidistant from the German Ocean and Adriatic: it enters Asia to the north of the Caspian. This line runs almost parallel with that of 10°C or 50°F., which is met with to the south of Iceland, in Lapland, and the north of Russia. That of 15°C. or 59°F. appears in the south-west of Ireland, the north of England, and in Norway, near to Bergen ; in Scandinavia, it rises till it cuts the isochimenal line of 23°F., and then, declining slightly, it enters Russia in the south of Finland ; its course is now parallel with that last described.

79. Sir John Leslie[1] and others have attempted to compute the mean temperature of any latitude by certain formulæ; but these expressions have failed to furnish correct results when applied generally. The most ingenious of these, is that of Mayer[2] of Göttingen, improved by Daubuisson,[3] and corrected by Sir David Brewster,[4]—namely, that the mean temperature decreases from the equator, as the squares of the cosine of latitude. Expressed symbolically, this law will be understood by the following formula,—where T represents the temperature required, at the level of the sea, and 81°.5 F., the mean temperature of the equator according to Baron Humboldt:—

$$T = 81°.5\ ^2 \cos. \text{lat.}$$

If the thermometric scale of Celsius or Reaumur be employed, then the expression will require, respectively, 27°.5 or 22° to be substituted for 81°.5.

80. The proximity of the ocean exerts a powerful influence in diminishing the rigour of the northern regions, and mitigating the heat of the tropical climes. In explanation, let it be premised, that the temperature of the ocean is uniform over a vast surface, and that changes do not suddenly take place; also, that from the great mass of water, local causes produce comparatively insignificant general alterations. Thus the cold winds which sweep over its surface in the temperate and frigid zones, are elevated in temperature before they reach the land. This arises from their communicating a partial chill to the particles of water upon the surface of the ocean which immediately descend, their places being supplied by others, warmer and of less specific gravity, thus establishing a current of heated particles upwards during the continuance of the wind. But this explanation, it may be said, does not account for the influence of the ocean in moderating the heat of the tropics. There, however, other causes tend to this result. If the temperature of the day be high, the cold produced by evaporation during the night is such that ice may

[1] Geom. Notes and Illustrations, p. 426.
[2] Opera Inedita; Playfair's Nat. Phil. 3d. Ed. vol. i. p. 296.
[3] Jour. de Phys. tom. lxii. p. 449.
[4] Ed. Tr. vol. ix. p. 201.

be produced, and the thermometer sinks even in India to nearly zero, although a few hours before the air was oppressively hot, about 900° F. becoming *latent* during the evaporation. Again, the trade winds, and in the North Atlantic the gulf-stream, are always exerting their heat-depressing influences upon the tropics. Thus it is, that an island enjoys a more equable temperature than a continent within the same parallel. Thus it is, that the temperatures of Edinburgh and Moscow are so dissimilar, and also those of Dublin and Labrador, of London and Prague. For a similar reason, the mouth of the St Lawrence is annually frozen, while the freezing of the Thames at London is an occurrence so rare as to become a historical fact. We have selected illustrations from nearly the same parallels of latitude.

81. Let us now consider the influence upon temperature of a wide-spreading continent unbroken by the sea. A wind sweeping over such a surface in summer, has its temperature raised by terrestrial radiation, while it reciprocates caloric to the ground; and thus it increases in temperature as it blows. The reverse occurs in winter. Radiation is then small; the ground is cooled to a low degree, and it abstracts caloric from the passing wind. If the wind shall have traversed a scorched desert, its baneful influence will not be more powerful than that of the wind which shall have swept the snow-clad summit of an alpine range: before both, nature languishes, and the withered leaf rustling in the blast, sings its melancholy dirge. Italy, protected by the wide Mediterranean, enjoys perhaps the finest European climate; while Pekin, which is nearly in the same parallel, suffers alternations of heat and cold between widely separated extremes. At Rome, while the temperature of the warmest month is 77°, and that of the coldest 42°, at Pekin the thermometer oscillates between 84°.4 and 24°.6 F. Woods, by excluding the solar rays, and sheltering the winter's snow, produce a greater cold than the latitude in which they grow would have led one to expect.

82. The following instances of European frosts are among the most remarkable of those recorded:—The freezing of the

Black Sea is referred to by Ovid,—"ingentem glacie consistere pontum;" and in the year 401, it was frozen over for twenty days.[1] From October 763 till February 764, a frost continued at Constantinople; both the Euxine and Propontis were frozen 100 miles from shore.[2] In the year 860, the Rhone was frozen. On midsummer-day in 1035, the frost was so severe in England that fruits were destroyed.[3] In 1063, the Thames was frozen for fourteen weeks. In the years 1149, 1263, and 1269, it was again frozen.[4] In 1294 and 1323, the Baltic was frozen. In the year 1334, a frost of two months and twenty days' duration, froze the rivers of Italy and Provence. In 1402, the Baltic was again frozen. From November 24. 1413 to February 10. 1414, the Thames was frozen to Gravesend. In 1426 and 1460, the Baltic was locked in ice. In 1507, the harbour of Marseilles was frozen over. In 1515, carriages crossed the Thames upon the ice from Lambeth to Westminster. In 1544, and previously in 1468, wine was cut by hatchets in Flanders. In 1548, the Baltic was frozen over. In 1564, from December 21. to January 3. 1565, the Thames was covered with ice.[5] In 1565, loaded waggons passed over the Scheldt. In 1594, the Scheldt, Rhine, and sea at Venice were frozen. In 1607, fires were kindled on the ice upon the Thames. In 1622, many European rivers, the Zuyder Sea and Hellespont were frozen. In the years 1657 and 1667, the Seine was frozen. In 1658, the Baltic was frozen over, and Charles X. led his whole army across from Holstein to Denmark. In 1683–84, the Thames was frozen eleven inches deep.[6] In 1708, the ice was twenty-seven inches thick in the harbour of Copenhagen, and in April 1709, people passed on the ice between Schonen and Denmark;[7] both at Genoa and Leghorn the sea was frozen. From Nov. 24. 1716 to Feb. 9. 1717, the Thames was again frozen; fairs were held and oxen roasted. In 1740, it was again covered with ice, and festivities held. In 1783, frost was observed in June.[8] In 1788–89,

[1] Univ. Hist.; Hayden's Dict. Dates, 1845, p. 224. [2] Ibid.
[3] Speed. [4] Holinshed—Chronicles, fol. 2d ed. vol. iii. pp. 58, 263, 274.
[5] Ibid. vol. iii. p. 1208.
[6] Evelyn's Mem.; Phil. Tr.—Motte's Abr. vol. ii. 102.
[7] Ph. Tr.—Motte, vol. ii. 100. [8] Sir John Cullum—Phil. Tr.

the Thames was passable on the ice opposite the Custom House, from November to January. In 1794–95, Pichegru's army was encamped upon the ice in Holland. In 1813–14, the Thames was again frozen, and booths were erected on the ice; the frost was intense in Ireland. In 1823, that river was once more locked in ice. Arago[1] has collected observations on the freezing of the great European rivers,—the Rhine, Danube, Rhone, Seine, Po, and others,—to shew that the cold of modern times has not been in general more intense than in ancient days.

83. It is generally believed that the temperature of the Southern, is lower than that of the Northern Hemisphere. Dr Robertson,[2] the historian, observes, that "if from the southern tropic we continue our progress to the extremity of the American continent, we meet with frozen seas and countries horrid, barren, and scarcely habitable for cold, much sooner than in the north." Captain Cook returned, after reaching S. lat. 71° 11′. Since then a farther advance has been made by Weddel and Biscoe, who made the interesting discovery of extensive land in the antarctic circle; and more recently, Sir James Clark Ross has gained S. lat. 78° 10′, 160 miles from the south magnetic pole. Baron Humboldt observed the difference, even in the 23d parallel. Ice approaches from 6° to 7° nearer to the equator on its southern side, and occasionally icebergs have been seen off the Cape of Good Hope in lat. 36°—39°. One was witnessed there measuring two miles in circumference, and rising above the sea 150 feet; others were from 250 to 300 feet above the waves, and consequently of great volume, for it has been demonstrated that in sea-water ice sinks nearly eight cubic feet for every solid foot above the water. Nevertheless, the southern hemisphere is less encumbered than the northern with ice,—a peculiarity arising from physical circumstances, which lead to its more speedy solution. Weddel did not meet with ice till he reached

[1] Annuaire du Bureau des Long. 1834.

[2] Hist. Amer. vol. i. p. 218, notes 31, 33; Anson's Voy. p. 74; Voy. de Quiros chez Hist. de Gen. des Voyages, tom. xiv. p. 83; Richard—Hist. Natur. de l'Air, tom. ii. 305; Hist. des Naviga. aux Terres Austral. tom. i. p. 47, ii. 256; Hawkesworth—Voy. i. 25, Byron; Cook's Voy. vol. ii. 217.

S. lat. 52° 31′, near the South Shetland and New Orkney Islands, and in S. lat. 70° he found open sea. It was observed by Cook, that the Pacific was more clear of ice than the South Atlantic Ocean. Owing to the groups of islands, and the land discovered by Biscoe,[1] ice advances between the meridians of 40° W. and 60° E., to S. lat. 51°; and a faint idea of the magnitude of the collections of ice in the antarctic lands may be obtained from the fact, that Sir J. C. Ross[2] in 1841, had his progress southwards arrested by a precipitous icy wall on Victoria land, rising to the height of 200 feet, and above a thousand thick, along which he sailed for 450 miles: there he found soundings of 410 fathoms.

84. The explanation of the difference in the temperatures of the hemispheres, is chiefly the peculiar form of the land, tapering, as it does, in all the continents to the southern pole, causing a great disproportion between the land and sea. Much freedom is thus given to ocean-currents to float the ice towards the equator; and thus, by the absorption of caloric during the melting of the ice, the temperature of the air falls below that of similar northern latitudes. Besides these causes, the agency of winds, as observed by Acosta,[3] must be taken into account; and, as Martins has suggested, the radiation of heat into space, which may be greater on that, than upon the northern side of the equator.

85. The subject of temperature may be fitly closed with a few remarks upon that of planetary space. The solar rays, in their passage through the pellucid regions of the sky, before they reach our atmosphere, contribute to it no increment of heat. It is by absorption of caloric that heat is developed; and experiment shews that opaque and translucent substances alone possess the power of absorbing warmth from his beams. We have already mentioned that the atmosphere absorbs a small portion of the calorific rays, but its altitude is as nothing in comparison with planetary space. Baron Fourier computes the radiation of *central heat* at only the $\frac{1}{30,000}$th part

[1] Geograph. Jour. iii.

[2] Sir James Clark Ross,—Voy. of Discov. 1839–43, Lond. 1847.

[3] Hist. Nat. &c. lib. ii. iii.

of a second in a century; consequently, whatever may be the internal temperature of our globe, it cannot influence that of space. The radiation of solar heat from the earth's crust scarcely reaches our own satellite, whose rays have been always accounted destitute of caloric, till now that Melloni has detected the merest thermic impressions. Guarding against atmospheric currents and other sources of error, Melloni, by condensing the lunar light with a lens three feet in diameter upon his thermiscopic pile, found the needle to deviate from 0°.6 to 4°.8, according to the phase. We cannot, therefore, suppose that space is warmed by our earth; and those objections which are found to apply to heat issuing from the sun, may be urged to that of stellar emanations. Fourier,[1] in his investigations upon internal heat, has estimated the temperature of space at 50° C. below zero, or —58° F. This acute and profound mathematician founded his inquiries on the laws of radiation from the earth's surface, on the hypothesis that our globe was once a molten mass, now arrived at nearly the limits of cooling from its pristine state. This theory requires a few passing explanatory observations. We have mentioned the hypothesis of a central heat, which direct experiment goes far to establish. But, it may be asked, if there does exist an intense internal heat, why is it not apparent to our senses? Simply because the materials composing the crust of our globe are feeble conductors of caloric. The upper strata of the globe are warmed by the solar rays through conduction, and cooled by radiation. As we sink thermometers in the earth, they gradually fall till we arrive at a limit—the "couche invariable" of Fourier, about 100 feet in depth—where the temperature is constant.[2] Below this line, and in proportion to the descent, the temperature rises,—an increment explained by the hypothesis of "central heat."[3] With different data, Svanberg[4] has

[1] Essai sur la Temp. du Globe, &c., Ann. de Chimie et Phys. xxvii. Oct. 1824.

[2] Pouillet's Elem. de Physique et de Météorologie, 8vo, tom. ii. p. 642; Encyc. Br. 7th Ed. vol. vi. p. 745.

[3] Ed. New Phil. Jour. vols. v. vi.; Annal. de Chimie, xiii. 211; De la Beche—Man. of Geol.; Annal. du Museum d'Hist. Nat. 1827; Pog. Annalen. xv. xxii. 146; Ed. Jour. of Sc. ap. 1832; Ph. Mag. 1830; Wahlenberg—Gilbert's Annalen. der Physik; Forbes,—Brit. Assoc. 1832, Rep. vol. i. p. 224.

[4] Bib. Univ. xliii. 367; Ed. Jour. of Sc. N. S. iii. 13.

arrived at the same conclusion with Fourier. He found the temperature of space to be — 58° F., upon the investigations of Lambert relative to the capacity of our atmosphere for caloric and the absorption of solar light. But these similar yet independent results, are widely different from that of Pouillet,[1] who, experimenting with swandown and delicate thermometers, exposed during serene nights to *celestial* radiation, arrived at the conclusion, that the temperature of space is so low as —140° C. or — 220° F. The extraordinary difference between the deductions of Fourier and Svanberg from the purest mathematics, and the practical results of Pouillet, dispose us to doubt the correctness of the inference of the latter. Melloni[2] observes that stagnant air may, in the phenomena of nocturnal radiation, affect such experimental researches.

86. Whence this celestial temperature? The phenomena regarding caloric with which we are acquainted, cannot explain it, and Kepler's[3] conjecture of the stellar radiation, is inadequate. Shall we seek the cause in the presence of an etherial fluid *sui generis*, existing above our atmosphere and pervading space? Of such a fluid, however, we possess no positive knowledge. It has been thought that some peculiar effects upon light are produced by it, and that it retards certain comets; but before we grant the latter supposition, it requires to be proved that the perturbations of these bodies do not arise from the attraction of primary planets.

While we are pleased with the poetic fancy of the ancients, we do not accede to their speculations,—

> "Ignis in ætherias volucer se sustulit oras;
> Summaque complexus stellantis culmina cœli,
> Flammarum vallo naturæ mœnia fecit."
>
> MANILIUS.

[1] Elem. de Phys. tom. ii. 538; Compt. Rend. 1838, tom. vii. 53.

[2] Comp. Rend, No. 15, tom. xxiv.

[3] Paralipomena ad Vitellionem, quibus Astron. optica traditur, 4to, 1604, xxxii. 25.

CHAPTER V.

87. Colour of the Atmosphere. 88. Saussure's observations with the Cyanometer. 89. Peculiar depth of colour, and clearness at great altitudes. 90. Theory of tints at sunset. 91. Crepuscular light; coloured shadows. 92. Theory of colours universally applicable. 93. Crepuscular rays; diverging and converging beams. 94. Transparency of the atmosphere. 95. Use of the Photometer. 96. Direct solar light; suffers defalcation; reflected light. 97. Dark lines; nature of light. 98. Refraction; amount. 99. Illustrated; remarkable examples. 100. Polarization of light,—by refraction; by reflection: discovery of Malus. 101. Polarization of the atmosphere: neutral points of Arago, Babinet, and Brewster; normal and abnormal changes in their position, 102. Secondary neutral points; influence of luminosity. 103. Twilight; cause. 104 Conducive to our comfort. 105. Anti-twilight. 106. Second twilight. 107. Duration. 108. Anomalous brightness in 1831. 109. Peculiarities at the Pole. 110. Feelings produced by perpetual sunshine. 111. Powerful influence of solar beams in arctic regions. 112. Twinkling of the stars. 113. Influence of the atmosphere on life.

> "I love thee twilight! as thy shadows roll,
> The calm of evening steals upon my soul,
> Sublimely tender, solemnly serene,
> Still as the hour, enchanting as the scene."
>
> JAMES MONTGOMERY, Esq.

> "Oh twilight! Spirit that dost render birth
> To dim enchantment; melting heaven with earth,
> Leaving on craggy hills and running streams
> A softness like the atmosphere of dreams;
> Thy hour to all is welcome."
>
> MRS NORTON.

> "Night wanes; the vapours round the mountains curl'd
> Melt into morn, and light awakes the world."
>
> BYRON,—*Lara*.

87. The colour of our atmosphere is appreciable only in the aggregate. Like water, it is clear, transparent, and in small quantities colourless; but when viewed through its full extent, it is of a beautiful cerulean blue, varying from a blue

approaching to white, to blue approaching to black, according to the zenith distance of the spot, and altitude of the observer. These changes depend upon the relative quantities of opaque vapour present at the time, the particles of which reflect chiefly blue and bluish-white rays ; hence it follows, that in those regions where their amount is least, the sky is darkest, and as the eye pierces a greater quantity of these molecules when directed towards the horizon, we find that in proportion as the visual angle is diminished, the shade becomes lighter. Sir David Brewster has proved by the polarization of light that the blue colour of the sky depends upon rays which have suffered reflexion by the entities of our atmosphere.

88. With the view of tabulating for comparison the various shades, M. de Saussure constructed an instrument called the Cyanometer, which is divided into 53 degrees of intensity.[1] It is well adapted for the object, but a serious objection arises if constructed as originally directed, for two can scarcely be found exactly alike. With such an instrument, Saussure made the following observations:—On Mont Blanc, at an elevation of 15,750 feet, the colour of the sky was 39°, on the Col du Géant 31°, at Chamouni 19°, and at Geneva 22°. Two hourly observations[2]—from 4 A.M. to 8 P.M. inclusive—on the Col du Géant and at Chamouni, gave the following results: for the *zenith*, 15.6, 27.0, 29.2, 31.0, 31.0, 30.6, 24.0, 18.7, 5.5,—mean for the former locality, 23.6 ; 14.7, 15.1, 17.2, 18.1, 18.9, 19.9, 19.9, 19.8, 16.4,—mean for the latter, 17.8 : for the *horizon*, 4.7, 7.5, 8.4, 9.7, 11.5, 7.6, 5.5, 4.7,—mean for the Col du Géant, 6.6, the observation at 8 P.M. being wanting ; 5.5, 7.0, 8,3, 8.6, 9.1, 9.3, 8.8, 8.4, 5.0,—mean for Chamouni, 7.8. Zenithal observations made two hourly, from 6 A.M. to 6 P.M., inclusive, at Geneva, gave the following indications, 14.7, 21.0, 22.6, 22.5, 20.4, 20.4, 16.3 ; mean 19.7. On the summit of the Monte Rosa on the 12th August 1819, M. Zumstein[3] observed the

[1] "L'entervalle entre le blanc pur, et le noir pur, s'est trouvé divise en 51 nuances." Voy. dans les Alpes, 4to Genève, 1786.

[2] Ib. § 2084. § 2085.

[3] Ed. Jour. of Sc., vol. i. p. 22.

cyanometer to indicate a depth of blue, of from 38° to 40°. Humboldt when passing from Corunna to Cumana, observed the cyanometer indicated a shade varying from 13° to 24°, and from 24° to 16°. In Europe, Caraccas and Cumana, the general intensity was as 14, 18, and 24 respectively. The tint is fainter at sea than on land in consequence of the greater quantity of vapour floating in the atmosphere over the ocean.

89. Travellers among the Himmalehs have remarked the deep blue colour of the sky, which is often rendered more marked by the contrast with the snow, and such is the clearness of the air among those elevated mountains, that the celestial bodies shine with peculiar splendour, and stars of the 4th magnitude require a telescope of small power to be rendered visible at noon. Thus at Zinchin in Chinese Tartary, visited by Moorcroft, at an altitude of 16,136 feet, a transit-instrument of 30 inches shewed stars of the 5th magnitude in broad day; the moon rose without those beams which usually herald her approach, and the sun shone like a fiery orb.

90. The late Professor Leslie remarks, that "no substance can disclose its inherent colour but by a sort of internal secretion or dissection of the rays of light. The mere reflexion from the surface of a solid body could never betray its tints, for when rendered more perfect by polish, it would only, like a mirror, send back unchanged the incident beams. To detect the subjacent colour, it is necessary that the particles of light should at least penetrate under the surface, and after suffering a sort of chemical separation, should be again emitted. In transparent substances, whether solid or fluid, the penetration is greater, but the mode of evolving the native colours must be still the same. The atmosphere besides dispersing internally the blue rays, likewise reflects in various proportions the white light unaltered. The fact is established by some experiments of polarization, which shew that such simple reflexions are the most copious from the portion of the sky which is 90° from the sun, and regularly decline on either side to the opposite points, where they cease altogether.

"The white or compound beam of light suffering in its

passage through the air a continued defalcation of the blue rays, must as it advances assume the complementary colour, or the tints of the remaining portions of the spectrum, and therefore merge successively into yellow, orange, red, and crimson. Such accordingly are the graduating colours of the solar rays as they approach to their extreme obliquity. Near sunsetting, the shadow of a pencil along a blank card appears a bright azure on a lilac ground. When a diffuse attenuated vapour reflects the incident light unaltered, the western sky, as the sun declines from his altitude, glows with the successive shades of yellow and orange, which deepen finally into a blush red. These colours again may, under certain circumstances, come to be blended with the natural blue of the atmosphere. Hence the explication of a curious phenomenon which rarely occurs in this climate, the existence of *green clouds.* This happens in the mornings and evenings, when a thin cloud is illuminated, at once by the yellow rays of the sun, and the bright azure of the upper sky, their contrasted colours producing a green by mixture. For the same reason, sometimes a portion of the bright sky appears in the finer climates tinged with violet. This was remarked by Humboldt in his voyage to America, and we have had occasion to observe the same at Avignon. It was no doubt occasioned by the reddish rays of the declining sun dying the intense blue of the higher atmosphere." The snow-topped Alps reflecting the sun's rays with great obliquity, as he sinks in the horizon, glow with rosy red, deepening in the twilight, by a similar cause.

"The snows above
The very glaciers, have his colours caught,
And sunset into rose-hues sees them wrought
By rays which sleep there lovingly."
Childe Har. iii. st. xcix.

A second rosy colouring of these mountains sometimes appears, fainter than the first, and of shorter continuance. Necker de Saussure[1] considers it an effect of contrasting colours ; but M. de la Rive[2] with greater correctness views it as the result of

[1] Annal. de Chim. et de Phys. 70.
[2] Brit. Assoc. 1837 ; Athen. No. 517, p. 692.

a peculiar condition of our atmosphere. It occurs, he observes, when the atmosphere is very transparent, highly charged with invisible moisture, and when the sun has so far descended below the horizon that his rays are reflected instead of refracted in the higher regions; an effect which is facilitated by the humidity of that portion of the atmosphere traversed by the rays, till they reach the incident point whence they are reflected.

91. In the western horizon above the coloured segment, which attends the setting sun, there may be observed a white arc, the *crepuscular light* of Brandes. About this period of the day those curious optical phenomena, called *coloured shadows*, are sometimes visible. The natural colour of a shadow is black, but when other lights are present than that which causes the shadow, various hues, but chiefly blue, may be assumed. Blue shadows arise from strong illumination by the azure sky, the sun at the same time casting a different tinge upon the margin of the projected figures, and thus rendering the phenomenon more distinct.

92. The theory of the colours of the sky which we have endeavoured to describe, is of universal application. It is to the same absorbing and reflecting powers, unequally possessed by different bodies, that we owe the beautiful diversity of tints in nature. The gorgeous plumage of the feathered tribe within the tropics, and the no less lovely snow-white dress of birds within the arctic zone, depend upon the same cause, which in the vegetable world at one time dazzles with the splendour and depth of the colouring, and at another, subdues with a lively yet mellow hue, while by a happy blending of all the tints, it produces an effect exquisitely pleasing.[1]

93. There is a phenomenon not unfrequently seen, and

[1] This explanation depending upon the *undulatory theory of light*,—a theory, which assigns to every hue a particular number of undulations in a fixed time,—numbers as amazing as the inconceivable velocity of the *fluid*, and determined by refined measurements,—is not the only theory propounded. We would refer to the *obstruction theory* of the poet Goëthe, according to which hypothesis, white light passes where there is no impediment, yellow when there is a slight obstruction, then red, and after that blue, according to the thickness of the opposing medium, till blackness results when the body is wholly impervious. *Vide* Goethe's Theory of olours.

then, generally when the sun is near the western horizon, and clouds are gathered round his disc but not in the form of a continuous mass ; on such occasions, the floating dust and vapours assume the form of beams issuing from his centre,—*crepuscular rays*, or *diverging beams*. When the phenomenon is seen in greatest splendour, *converging beams* likewise appear centring in a point diametrically opposite the sun, and as many degrees below, as his disc is then above, the horizon. The converging rays are more feeble than those which diverge, and are best seen when projected on a dark cloud. The explanation of the converging rays is easy ; they are merely continuations of those in the west, seen perspectively. The point of greatest divergence is 90° from the sun, and the line joining his centre, and that of convergence passes through the spectator. These diverging and converging rays are mentioned as having been seen by Faraday, in the Isle of Wight, at sunset in the month of August ; by Saussure,[1] on his ascent of Mont Blanc ; by Mohs and Haidinger, near Freiberg ; by Dr Smith ;[2] by Sir David Brewster,[3] on the 9th October 1824, between Melrose and Edinburgh ; and again, on the 2d of October 1828, when the phenomenon appeared within a rainbow. Converging rays were observed in 1824, at Aberdeen and at Leith,[4] and in the following year at the latter place.[5]

94. The transparency of the atmosphere depends upon various causes, such as temperature, humidity, and altitude. The higher the place of observation, the clearer the air will appear, for the opaque particles upon which diminished transparency depends, are generally floating in the lower strata of the atmosphere. It is true that a moist air affords a very extensive and distinct vista, if the humidity is not excessive, but it does not follow that a dry air is not pellucid. The intensity of the solar light, together with adventitious particles floating about during a drought, and the immense volumes of smoke which arise from cities and manufactories where it is not con-

[1] Voy. dans les Alpes ; Annal. de Ch. tom. lxx.

[2] Optics, vol. ii. p. 57.

[3] Optics—Lardner's Cab. Cyclop, ; Ed. Jour. of Sc., vol. ii. p. 137 : Ib., vol. x. p. 163.

[4] Ed. Jour. of Sc., vol. iii. p. 52.

[5] Ib., vol. v. p. 85.

sumed, blending with the air in dry weather, tend to diminish the transparency of the atmosphere. Such is its clearness among the Andes, that at Quito, the *poncho* or white mantle worn on horseback, has been distinguished at a horizontal distance of 84,032 feet, or about 16 miles ![1]

95. The intensity of light may be measured by a beautiful instrument,—the *Photometer,*—invented by Sir John Leslie, who, in describing its use, says, that "when placed in the open air, it exhibits distinctly the progress of illumination from the morning's dawn to the full vigour of noon, and thence its gradual decline till evening has spread her mantle; it marks the growth of light from the winter's solstice to the height of summer, and it enables us to compare with numerical accuracy the brightness of different countries, the brilliant sky of Italy, for instance, with the murky atmosphere of Holland.[2]

96. The light of the sky is derived from two sources, the direct solar rays, and those reflected. The amount of light falling upon a horizontal surface being proportional to the sine of its obliquity, it follows that as the sun's rays are darted from a lower altitude, the intensity of light is lessened; hence the amount of solar light is variable, depending upon hour and season. In this climate, the variations between midsummer and winter are from 90° to 25° of Leslie's photometer. At an altitude of 17° the reduction is equal to one-half, and when the sum is only 3° above the horizon, the entire effect does not exceed one millesimal degree.[3] But the direct solar rays suffer defalcation in their passage through the atmosphere just as those of heat sustain a loss in their transmission to the earth. Sir John Leslie computes the loss of one-fourth upon a beam of light darted to the earth under the most favourable circumstances; and he observes, that if the tract of light follows in arithmetical progression, the intensity is diminished in geometrical progression. On the meridian, only $75\frac{0}{0}$ reach us; at an altitude of 80°, the amount equals $74\frac{0}{0}$; at $60° = 72\frac{0}{0}$; at $45° = 66\frac{0}{0}$; at $35° = 60\frac{0}{0}$; at $25° = 50\frac{0}{0}$;

[1] Edin. New Ph. Jour.; Arct. Reg. vol. i. p. 110.

[2] Encyc. Brit., vol. xiv. p. 739, 7th Ed. [3] Ib.

at 15°—33% ; at 10° = 20% ; at 5°—5% ; and on the horizon, only 0.00002. At the equator, in mean latitude 45°, and at the pole, the annual quantity of *direct* solar light which falls upon the earth, is computed to equal a constant illumination from altitudes of 17° 46′, 13° 2′, and 7° 17′ respectively ; consequently, under the most advantageous circumstances, out of a thousand luminous beams, only 378 of the oblique rays reach the earth at the equator, 228 at lat. 45°, and nearly 110 at the pole.[1] The amount of *indirect* or reflected light varies in our climate from 30° to 40° in summer, and from 10° to 15° in winter. It is most intense when thin fleecy clouds overspread, and feeblest when thick vapours cover the sky, or when it is deeply azure.

97. A beautiful discovery of Wollaston and Fraunhofer has demonstrated a deficiency in the pencil of solar light, supposed to arise from absorption in the sun's atmosphere. When the spectrum is received upon the object-glass of a telescope a number of dark bands are found uniformly present. These spaces are supposed to arise from the cause mentioned. But what is the nature of the subtle fluid of which we speak? As yet we are ignorant. Nevertheless, two theories have been proposed and ably supported. It is foreign to our object to examine these hypotheses, suffice it merely to name them. The one is the *emission theory* of Newton ; the other is the *undulating theory* of Huygens, and Dr Thomas Young. By the former, light is assumed to be material and darted from all self-luminous bodies ; by the latter, it is believed to reside in a subtle fluid, an ether, pervading space—luminous when in motion, dark when in repose. By the undulatory theory, the particles of this ether are supposed to be easily agitated and cast into regular vibrations, propagating the motion like a ripple on the water. The intensity of light is believed to depend upon the extent of the undulations ; its colour, upon their frequency.

98. When a ray of light passes obliquely through media of different densities, it is bent, deflected, or refracted from its straight course towards the denser medium, in a *vertical* plane.

[1] Encyc. Brit., vol. vi. p. 748.

This is *ordinary refraction*, and it happens in our atmosphere, the refraction of solar light being increased in proportion to the density of the air. Consequently, the nearer the ray approaches to the earth's surface, the more it is deflected from its rectilinear path; and in proportion as it enters the atmosphere upon or near the horizon the refraction is augmented. In the zenith there is no refraction. This important fact was known to Ptolemy,[1] so early as the 2d century; but it must have been forgotten, for Tycho, in the 15th century, supposed refraction to terminate at an angle of 45°, and it was not till Cassini rediscovered its amount, that astronomers were agreed upon the position of this non-refracting spot. At the horizon, the refraction,[2]—barometer 30 inches, and thermometer 50° F. (or rather 48°),—amounts to 33′ 51″, at 1° it equals 24′ 25″; at 2° = 18′ 29″; at 3° = 14′ 35″; at 5° = 9′ 58″; at 10° = 5′ 20″; at 25° = 2′ 4.2″; at 45° = 58.1″; at 60° = 33.6″; at 89° = 1″. But as refraction depends not only upon altitude, but upon barometric pressure, temperature, humidity, and according to Piazzi,[3] electricity, agents which are ever varying, the best table is incomplete without corrections.

99. But how, it may be asked, is the existence of atmospheric refraction proved? Astronomy furnishes abundant evidence. Let us select, in illustration, a star which in the latitude of observation is always above the horizon, *e. g. Dubhe* in the great bear (α Ursæ Maj.), whose north polar distance is 27° 19′ 58.4″, or the brilliant *Capella*, distant from the same point 44° 11′ 5.1″, and compare it with another star situated nearer to the pole, *e. g. Polaris*, whose north polar distance equals 1° 35′ 51.4″, then we shall find that the apparent distances of these stars change as they cross the meridian in the zenith, and pass it in the horizon. Now this is only an apparent change, constantly recurring but variable,

[1] "Optics"—a work lost sight of from the time of Roger Bacon till recently, when two copies were found, one in Oxford, and the other in Paris. Cassini uses the same diagram employed by the Alexandrian Astronomer, and nearly the same reasoning. Rep. on Optics. Brit. Assoc. 1832, vol. i. p. 309.

[2] Enc. Br. vol. iv. p. 100; Ph. Tr. 1819; Bailey's Tables and Formulæ; Pearson's Tables; Naut. Almanac, 1833; Annuaire du Bur. des Long. 1806; Berliner Jahrbuch. 1816, &c.

[3] Memorie della Società Italiana, 1804.

and owing to some terrestrial influence,—to refraction.[1] Another proof is furnished in the increased horizontal diameter of the sun and moon when they rise and set, but particularly when declining in the west, amounting in some instances to one-fifth of the entire diameter of the disc. This distortion arises from the apparent shortening of the vertical axis.

In 1750, a remarkable illustration of atmospheric refraction occurred at Paris. The sun was setting, but his disc was still above the horizon, when the moon rose in a total eclipse. A similar phenomenon occurred on the evening of the 20th of April 1837 in this country, though invisible at Edinburgh in consequence of clouds. The same was witnessed on the 20th September 1717. The true position of these bodies at the time was diametrically opposite, with the earth between, a straight line passing through their centres; consequently, one of them, or the semidiameter of each, must have been below the horizon, when both were visible above it. During Parry's Polar Expedition,[2] on the 3d of February 1820, in lat. 74° 47′, the sun re-appeared after an absence of ninety-two days, three days sooner than by calculation it should have been seen in that latitude. Barentz saw his disc at Nova Zembla, January 24. 1597, fifteen days before his return was expected. Being ignorant of the cause of the phenomenon—the increased refractive power of polar air,—he disputed the correctness of the observation of De Veer, till at last he yielded to ocular proof! So much for the nicest computations when made upon limited data. This recalls to mind the miraculous lengthening of the day when Joshua was engaged in combat with the Amorites. Then the sun did not set on Gibeon, and the moon tarried in Ajalon.[3] Though we doubt not the power of Him who said and it was done, to hold the earth "in the hollow of his hand," while it ceased to perform its diurnal revolution—to stay the moon in her orbit, and prevent her rotating on her axis—to interpose His Almighty arm between the other members of the system and

[1] See Carlini—Milan Ephemeris, 1806.

[2] Fisher's Arct. Jour.

[3] Josh. x. 12; Josephus Ant. Book V. ch. i.

physical disturbances—these, and more if required, we freely grant, still we humbly think that this miracle was wrought by the secondary influence of an unusual refraction. Another miracle, which we would explain in a similar way, was the returning of the shadow on the dial of Ahaz.[1] That that phenomenon was confined to the neighbourhood of Jerusalem, may be inferred from the arrival of ambassadors from the princes of Babylon, to inquire of Hezekiah "of the wonder that was done in the land" of Judah.[2]

100. The subject of atmospheric refraction affords an easy transition to that of polarization; but before we endeavour to describe the *polarization of the atmosphere*, a brief notice of the discovery of Malus may not be deemed unnecessary. About the middle of the 17th century, Erasmus Bartholinus[3] had noticed the peculiar property of Iceland spar[4] to produce double refraction; the subject was more carefully examined by Huygens,[5] and it occupied the attention of Sir Isaac Newton.[6] Previous to this, philosophers were acquainted with *ordinary refraction* (see 98) merely; but now a curious property was discovered to exist in almost all crystalline bodies,[7] and it required the genius of Fresnel to unite by a beautiful generalization, "perhaps the greatest variety of facts that have ever yet been arranged under one general head."[8] If a ray of light[9] which has neither been reflected nor refracted previously, fall upon a rhombohedron of Iceland spar in the direction of its optic axis, it will suffer no change in its properties, although it will be refracted; but if it fall upon the crystal in any other direction, it will be bisected in its trans-

[1] Isa. xxxviii. 8; 2 Kings xx. 11.

[2] 2 Chron. xxxii. 31; Costard's Astron. Hist. 4to. 1767, pp. 47, 105.

[3] Exper. Cryst. Island. Dis-diaclastici, &c., Copenhag. 1669; Edin. Phil. Jour. vol. i. p. 291.

[4] The purest carbonate of lime = lime 56.15$\frac{3}{8}$ and carbonic acid 43.7,—Stromeyer.

[5] Traité de la Lumiere; Ed. Phil. Jour. vol. ii. p. 167; Ib. iii. 148.

[6] Optics, Book iii.

[7] All crystals the primitive form of which does not belong to the tessular system of Mohs,—the cube, regular octahedron, and rhomboidal dodecahedron, possess the property of double refraction.

[8] Sir John Herschel,—Discourse on the Study of Nat. Philos. p. 3

[9] *Common* light—either solar or artificial.

mission and experience a double refraction ; one of the pencils of light will proceed in the plane of the incident ray, but the other will be deflected from it at an angle of 6° 15′—the former suffers ordinary refraction, the latter experiences *extraordinary refraction*: both pencils of light, however, will be parallel to each other and to the incident ray, on emerging from the crystal, but they are no longer pencils of *common light*,—each differs from the other, and neither possesses the properties of the original beam. The *ordinary ray* in its refraction is obedient to the law of Snellius,[1] the angles of incidence and refraction preserving the same ratio, whether the ray impinges at 0° or 90°, but the *extraordinary* ray follows no such law. If the crystal be made to revolve, the ordinary ray remains stationary; but the other changes its position with the rotation of the mineral, and performs a revolution round the first.

If another rhomboid of Iceland spar be now placed symmetrically with, and behind, the first, the double pencils of light will suffer refraction through the second crystal; but neither will be bisected as in the former instance, although the *ordinary* ray is still refracted *ordinarily*. If the second rhomb be made to turn round while the first remains fixed, some curious results will be observed to follow—each pencil begins to divide into two. When the eighth part of the rotation has been performed, or when the crystal has revolved 45°, the whole of each of the rays is bisected, and four images of any luminous object viewed through the rhombs will be seen. When 1-4th of the revolution has been performed, or 90°, the four images are reduced to two, in consequence of the pencil, which by the first crystal was refracted ordinarily, being refracted extraordinarily by the second, and that refracted in the extraordinary way by the first, being refracted in the ordinary way by the second. When 3-8ths or 135°, have been performed, four images again appear, and a similar pheno-

[1] $\frac{\text{Sin. Ang. Incid.}}{\text{Sin. Ang. Refl.}}$ = Index of Refraction. In a vacuum there is no refraction, but in tables it is generally made 1.0 as a standard of comparison. That of atmospheric air (thermom. 32° F., and barom. 29.922 in.), = 1.000294 ; oxygen, = 1.000272 ; nitrogen, = 1.000300 ; water, = 1.333 ; crown glass, = 1.535 ; flint glass, = 1.600 ; iceland spar, = 1.654 ; the diamond, = 2.475 ; and chromate of lead, = 2.975.

menon occurs at 5-8ths or 225°, and at 7-8ths or 325° of the revolution. When the rhomb has made half a revolution, or 180°, all the images coalesce into one bright image, four times brighter than any one of those visible in the positions of 45°, and 135°; at 3-4ths of a revolution, or 270°, two images are seen as in the first position of the crystals. Although the bisected pencils of light leave the crystal in parallel directions, the polarization takes place in planes at right angles to one another. "The ray of common light may be assimilated to a round rod, whereas the two polarized rays are like two parallel long flat rulers, one of which is laid horizontally on its broad surface, and the other horizontally on its edge."[1] This peculiar property of light has been termed *plane polarization by refraction*, the discovery of which was made by Huygens in the 17th century.

Towards the close of the first decade of the present century, Malus made the fine discovery of *plane polarization by reflexion*. While this distinguished and deeply-lamented man resided in the Rue des Enfers, in Paris, he happened one evening to observe the windows of the Luxembourg brilliantly illuminated by the setting sun. Taking up a crystal of the purest quartz, he viewed the spectacle through this refracting medium: as he turned it slowly round, he observed that one of the images suffered obscuration at certain angles of its rotation, the most refracted image being alternately changed from brightness to darkness at each quadrant of the revolution.

Malus found that when light is reflected at a particular angle from transparent bodies, whether solid or fluid, it acquires properties similar to those resulting from double refracting crystals. If a ray of light falls upon a piece of plate-glass at an angle of 57°, or upon water at that of 53° 11′, it will be reflected at a corresponding angle,—if it be now viewed through a rhomb of Iceland spar, or a prism of tourmaline, the phenomena of polarization will be manifested. The polarizing angle is different for different media. After many experiments to determine this, Sir David Brewster discovered

[1] Mrs Somerville,—Connex. Phys. Sc. sect. xxi.

in 1814, the elegant law, that the index of refraction is the tangent of the angle of polarization.[1] By this simple rule we can determine the angle at which light will be completely polarized by one reflexion, but if the number of reflexions be sufficiently great, light may be polarized at any incidence. When light falls upon transparent bodies, part of it suffers reflexion and part of it is transmitted; if these rays are polarized, the reflected pencil is polarized in the plane of reflexion, or *positively*; while the transmitted light is polarized in a plane at right angles to that of refraction, or *negatively*. These terms will be employed in the sequel.

We thus find, that while a ray of *common* light suffers double refraction upon passing through certain minerals, *polarized* light cannot be so divided excepting in certain positions of the crystal—that while common light may be oftener than once reflected at any incidence, polarized light cannot be again reflected at certain angles—that while common light after reflection will pass through transparent bodies, polarized light reflected at the polarizing angle loses that power in certain positions of these bodies.

101. With these preliminary remarks, let us endeavour to follow Sir David Brewster[2] in his description of the Polarization of the Atmosphere. When Malus closed his brilliant career at the early age of thirty-six, Arago in France, and Brewster at home, besides other distinguished philosophers, took up the subject, and contributed largely to our knowledge on this branch of physical science. The polarizing angle of air was estimated at 45°, and found to be very nearly at that angle; consequently, it was to be expected that the polarization of the atmosphere should be *maximum* in those parts of the sky where the solar rays are reflected at 45° or 47°, *i. e.* about 90° from the sun, in the plane passing through that luminary and the zenith; and *minimum* opposite to his disc, at an incidence of 0°, and in his immediate vicinity, where the incident and reflected rays form an angle approaching to 180°.

[1] $\frac{\text{Sin. Ang. Incid.}}{\text{Sin. Ang. Refr.}} = \text{Tang. Ang. Polariza.}$

[2] Physical Atlas, part 7,—chart, plate 5. Edin. 1848.

While M. Arago was examining the sky opposite the sun, he found that about 25° above the spot diametrically opposite his disc, or the *antisolar point*, there was a place in which no polarization existed. This has been termed the "antisolar neutral point," or *Arago's neutral point*. In 1840, another neutral point was discovered, situated *above* the sun, about the same number of degrees from his disc as the first is distant from the antisolar point. This second neutral point has been named from its discoverer, *Babinet's neutral point*. Between these neutral points the light is polarized in the plane of reflexion, or *positively;* while between the sun, and the antisolar point of Babinet's and Arago's neutral points respectively, the light is polarized at right angles to the plane of refraction, or *negatively*. Hence these neutral points arise from the neutralization of the positive and negative polarizations described—the negative light being "either produced by reflexion in a plane at right angles to that passing through the sun, the neutral point, and the observer, or by refraction in a plane passing through these three points, or by both these causes combined."[1] A few years ago, Sir David Brewster discovered a third neutral point, situated *below* the sun, and in 1845 he communicated the discovery to M. Babinet,[2] who, on the 23d of July 1846, confirmed its existence.[3] This point we would term *Brewster's neutral point*. Sir David Brewster was led to this discovery by finding *negative* polarization below the sun, but in consequence of the brilliancy of his rays, the discovery was delayed ; however, on the 18th of February 1842, at noon, when the sun's altitude was about 22°, he distinctly saw it, distant about 15° or 16° from his disc—the rays were polarized negatively between that point and the sun, and positively between the neutral point and the horizon. The first of these points is best seen after sunset ; the second immediately after sunset ; and the third, which is by far the most difficult to detect, at those seasons of the year when in our latitude it is brought above the horizon.

[1] Brewster,—Phys. Atlas.

[2] Comptes Rendus, tom. xxii. 17th Mars 1845.

[3] Ib. tom. xxiii. p. 195, 27th Juillet 1846; ib. p. 233, 3d Aout 1846.

These neutral points change their position, both in respect to azimuth and to one another, as the sun pursues his path in the cerulean vault. When the sun is in the horizon, Arago's neutral point is elevated about 18° 30′; but when the sun has risen between 11° and 12° the neutral point is in the horizon, and consequently distant from the antisolar point 11° or 12°. As the sun descends, and the antisolar point rises, the distance between the latter and this neutral point increases, and when his disc reaches the horizon the neutral point is 18° 30′ above it. When the sun has set, the distance between the antisolar point and neutral point increases to a maximum of 25°. From sunrise till the period of culmination, the neutral points of Babinet and Brewster approach his disc, and when he crosses the meridian the distance is a minimum; as he descends, these points again separate, till they attain their maximum distance when his disc is in the horizon. Within the tropics, where the sun is vertical, these neutral points coincide with the solar disc when he reaches the zenith. These we would account *normal* changes, but Sir David Brewster has shewn that the neutral points are subject to changes which we may term *abnormal*. For instance, on the 27th of April 1842, "the sky was singularly fine—the barometer at 30.04, and at $10^{h.}$ 41′ the maximum polarization of the sky 29½°, the greatest that I have observed. At $10^{h.}$ 45′, the distance of the neutral point from the sun was 12° 3′, and consequently about 33½° *above* the horizon. At $12^{h.}$ 12′, a fog came rapidly from the sea. The neutral point below the sun was driven beneath the horizon, and Babinet's neutral point rose almost to the zenith. At $1^{h.}$ 20′ the fog diminished. The neutral point below the sun reappeared near the horizon, oscillating up and down, through a space of 5° or 6°, as the fog became alternately denser or rarer!"[1]

102. Upon the 8th of June 1841, at $5^{h.}$ 50′, and on the 21st of April 1842, at $6^{h.}$ 22′ P.M., Sir David Brewster detected a secondary neutral point accompanying that of Arago, and separated from it by bands of negative polarization. The phenomenon was seen on the sea horizon of St Andrews, where

[1] Brewster,—Phys. Atlas.

an obscure band a few degrees high indicated the existence of a distant haze. On the first of these occasions, the positive polarization was strongest on, and for about 1° 30′ above, the horizon ; hence when the neutral point rose, it first appeared about 1½° above the horizon, the compensation being effected in the place where the positive polarization was weaker than in the horizon: this neutral point was seen in the midst of positive polarization. As the phenomenon became developed, negative polarization manifested itself, and the positive polarization was overcome, the ascending neutral point of Arago having negative polarization immediately below. A few degrees below this point, the secondary neutral point was seen ; it arose from the compensation of the negative polarization by the excess of positive polarization in the horizon. Sir David Brewster observes, that in certain states of the horizontal sky a secondary neutral point must accompany that of Babinet, and also that discovered by himself.

The presence of luminous clouds or illuminated terrestrial objects in their vicinity, or even of a luminous object in the field of view of the instrument, affects not only the amount of polarization of the sky, but produces a deviation in the plane passing through the neutral points, the sun, the antisolar point, and the eye of the observer ; and causes a change in the distance of these points from the antisolar point and the sun.

103. The twilight or *crepusculum* of the Romans, or in the expressive language of the Scotch, the *gloaming*, is that lengthening of the day which precedes the rising and follows the setting of the sun. Without it we should be plunged in midnight-darkness immediately upon his sinking in the west, and experience the brightness of noon, without the agreeable gradual increase of light, on the approach of that luminary in the morning. "Of all the periods of the day," says an elegant writer, "the hour that intervenes between the setting of the sun and the darkness of night, has ever been to us an hour the most valued, and often the most earnestly longed for. At that calm and meditative season, the remembrance of early days and the companions of our youth, rise up first

to our mental vision. We live over again, in a brief space, many a bright scene of that eventful period that lies undisturbed in the recesses of the memory, until that contemplative hour brings them forth."—Charles Moir, Esq.

The morning twilight begins when the sun is yet a few degrees (18°) below the horizon. His rays then illuminate the higher regions of our atmosphere: as he rises, though still invisible upon the plains, his beams may be seen to strike the mountain top, and by his heat, affords a pleasing transition from the coldest portion of the night.

> "As if they, conscious, quaffed
> The sunny flood, hill, forest, city, spire,
> Laugh in the wakening light."
>
> *Day-break.*

His rays are not only refracted, but reflected by the molecules of the air, and dispersed in all directions, producing this phenomenon. In the evening, the changes are the same, but in an inverted order. The sun has set, but his beams tarry upon the mountain, casting a warm gleam, dazzling perhaps its summit, and gilding with his rays the clouds.

> "Quum cærula nubes
> Solis inardescit radiis, longèque refulget."
>
> Virg.—*Æn.* viii. 621.

Gradually the molten mass blackens in the sky, the evening mist rolls down the mountain side, and darkness envelops the earth.

> "How beautiful is night!
> A dewy freshness fills the silent air.
> No mist obscures, nor cloud, nor speck, nor stain,
> Breaks the serene of heaven:
> In full-orb'd glory, yonder moon divine
> Rolls through the dark-blue depths.
> Beneath her steady ray
> The desert circle spreads,
> Like the round ocean, girdled with the sky.
> How beautiful is night!"
>
> Southey,—*Thalaba the Destroyer.*

104. The power which the particles of the atmosphere possess of reflecting and diffusing the solar rays, contributes

greatly to our comfort. Without it, the sun would be a brilliant orb shining in the midst of gloom, and those objects only upon which his rays directly strike would be illuminated. A flitting cloud would produce an awkward obscuration, and the stars would be seen by day. Sir John Herschel[1] has observed that "this scattering action of the atmosphere on the solar light, is greatly increased by the irregularity of temperature caused by the same luminary, in its different parts, which, during the daytime, throws it into a constant state of undulation, and by thus bringing together masses of air of very unequal temperatures, produces partial reflexions and refractions at their common boundaries, by which light is turned aside from the direct course and diverted to the purposes of general illumination."

105. Although it is the western horizon which glows most lovingly, still, immediately opposite the setting sun, especially under certain atmospheric conditions, the eastern sky partakes of the roseate hues. The intensity of this tinge is greatest at the moment when his disc sinks below the horizon. It is the last effort of the sun to dart his rays upon the sky before leaving us for the night, which reach us by reflexion, deprived of all their colours but the red. Below this, a deep blue or dusky-looking segment appears, and, when circumstances are favourable, it is well defined. This is the *anti-twilight* of Mairan: it is the shadow of our globe cast upon the sky. Two evenings before writing the preceding sentence, the author had a fine view of this pleasing phenomenon. It was on an autumnal eve, such as we often meet with in England, when the changing hues of the foliage add a charm to the landscape, glowing in the warm colouring of a lovely sunset.

106. A phenomenon termed the *second twilight*, is sometimes seen from lofty mountains. It consists of a nebulous light in the west, rising, according to Saussure, from observations on the Col du Géant, to an angular height of 30°; and according to Bravais, distant from 116° to 108° 34′ from the

[1] Astronomy,—Lard. Cyclop. p. 33.

zenith. It has been referred by Biot[1] to a secondary illumination of the higher atmosphere, from strata of air below the horizon receiving the solar beams directly.

107. The duration of twilight is variable, depending upon latitude and season. These are the primary causes of its inconstancy; but those conditions of the atmosphere which produce changes in refraction, operate as secondary causes. Its length within the tropics is, according to La Caille, between the period of sunset and the sinking of his disc 16° or 17° below the horizon; and that of morning twilight, from the time when the sun approaches the same number of degrees to the eastern horizon and sunrise: in other latitudes the angle amounts to 18 degrees. Sir John Leslie estimates the limit to a descent of 16° in warm climates, and 20° in the polar regions. Hence, there is no *real night* when the sun is less than 18° below the horizon. This happens in our latitudes, where at London the pole is elevated 51° 31′, between May 21st and July 22d, and at Paris in June. At Edinburgh, real night ceases from the 6th of May to the 7th of August. The shortest twilights at London, occur on the 1st of March and 16th October, when the length is respectively $1^{h.}$ $51^{m.}$ and $1^{h.}$ $54^{m.}$; the longest is at the summer solstice (21st June), when the interval between sunset and sunrise amounts to $7^{h.}$ 27^{m}; thus the range of twilight at London is $5^{h.}$ $36^{m.}$ When the latitude is less than 48° 30′, real night extends throughout the year.

108. We would observe that an anomalous brightness was witnessed in August and September 1831, over Spain, Italy, and Northern Germany, by which small print was visible at midnight. This was not explicable by crepuscular light, unless we suppose that the atmosphere was then unusually refractive and dispersive,—a state which might arise from the altitude of vesicular particles, and the transparency of the lower atmosphere.[2] And we are warranted to believe that such was its actual condition; for the barometer fell, the sun

[1] Mém. de l'Acad. des Sc. tom. 17.

[2] Biot's Tr. d'Astron. Physique. 1841, tom. i. pp. 171, 238, 312. Kamtz's Met.

nad a silvery whiteness, and storms blew both in Europe and in the West Indies during these months.

109. At the north pole there is night so long as the sun's declination is south, *i. e.* from the autumnal to the vernal equinox, or from the 22d September to the 20th March. Twilight appears, however, whenever the declination is less than 18°, and increases inversely as that luminary approaches the equinoctial line. From the autumnal equinox till the 12th of November there is a constant twilight, after which there is continual night till the 29th of January, when the crepuscular light again returns, and lasts till the vernal equinox. The sun now appears after his long absence, and for a full half-year illuminates those regions.

> "Shall spring to these sad scenes no more return?"
>
> BEATTIE.

> "Wish'd spring returns; and from the hazy south,
> While dim Aurora slowly moves before,
> The welcome sun, just verging up at first,
> By small degrees extends the swelling curve,
> Till seen at last for gay rejoicing months,
> Still round and round his spiral course he winds;
> And, as he nearly dips his flaming orb,
> Wheels up again, and re-ascends the sky."
>
> THOMSON,—*Winter*, v. 866, *et seq.*

Then, says Captain Beechey, "all nature seems to acknowledge the glorious sunshine, and the animated part of creation to set no bounds to its delight. Here we cannot fail to notice the manner in which the great Author of nature has varied his dispensations. In the burning regions of the torrid zone, the descent of the sun calls into action myriads of little beings, which could not exist under the fierce glare of his meridian ray; whereas here, on the contrary, it is the signal for universal repose. This period had no sooner arrived in Magdalena Bay, than there was a stillness which bordered on the sublime,—a stillness which was interrupted only by the bursting of an iceberg, or the report of some fragment of rock loosened from its hold. These sounds, indeed, which came

booming over the placid surface of the bay, could hardly be considered interruptions to the general silence; for speedily dying away in the distance, they left behind a stillness even more profound than before."

110. Describing the feeling which perpetual sunshine in those regions produced, Captain Beechey[1] says:—"The novelty, it must be admitted, was very agreeable; and the advantage of constant day-light, in an unexplored and naturally boisterous sea, was too great to allow us even to wish for a return of the alternations of day and night: but the reluctance we felt to quit the deck when the sun was shining bright upon our sails, and to retire to our cabins to sleep, often deprived us of many hours of necessary rest; and when we returned to the deck to keep the night-watch, if it may be so called, and still found the sun gilding the sky, it seemed as if the day would never finish. What, therefore, at first promised to be so gratifying, soon threatened to become extremely irksome; and would, indeed, have been a serious inconvenience, had we not followed the example of the feathery tribe, which we daily observed winging their way to roost with a clock-work regularity, and retired to our cabin at the proper hour, where, shutting out the rays of the sun, we obtained that repose which the exercise of our duties required. At first sight, it will no doubt appear to many persons that constant day-light must be a valuable acquisition in every country; but a little reflection will, I think, be sufficient to shew that the reverse is really the case, and to satisfy a thinking mind that we cannot overrate the blessings we derive from the wholesome alternations of labour and sleep, which is in a manner forced upon us by the succession of day and night."

111. In June and July in the arctic regions the sun is powerful, and the temperature often sultry, causing great evaporation, and a very humid atmosphere. Its influence upon vegetation is remarkable, for scarcely has the long night of

[1] Voyage of Discovery towards North Pole. 1818.

winter passed, than saxifrages and other flowers are seen in blossom.

> "Sudden on the wondering sight,
> Bursts forth the beam of living light;
> And instant verdure springs around,
> And magic flowers bedeck the ground."
>
> HERBERT,—*Helga*, Canto vi. 1.

Sir John Leslie[1] observes, that the solar heat at the summer solstice is capable of melting at the pole, a sheet of ice an inch and half thick in course of a day. The powerful influence of the summer sun cannot be better illustrated than by the following extract from a letter of Captain Ross, dated 11th July 1848:—"It will, perhaps, surprise you, when you hear me state, that it has been so warm during our stay here, that the men have been all working in their shirts,—that is, without jackets or waistcoats, and with necks bare, *a la* Mediterranean."[2] The ships were at that time at Uppernavic, the northernmost colony of Greenland, moored to an icefield of great magnitude.

112. The twinkling of the stars, arising from the apparent displacement of their position through a constant vibration of the air, is another effect of atmospheric refraction. These scintillations are best seen when strata of air, of unequal temperatures and density, move one above the other, as explained by Hooke. We have frequently observed a similar appearance on the sun's disc, when viewing that orb through a powerful telescope. And, doubtless, to similar atmospheric changes must be referred the alterations in the stars' brightness and tint,—we do not refer to *variable stars*,—changes, giving rise to irregularities in the amplitude and velocity of the luminous undulations upon which the phenomenon depends. Thus have we seen the bright and lovely *Sirius* sparkling alternately in blue and crimson, when the atmosphere has been more than usually humid. Baron Zach[3] observed a curious scintillation of the stars at Genoa, on the morning of the 12th October 1823, when they appeared to

[1] Ed. Cab. Lib. Pol. Seas, p. 30. [2] *Witness* of October 11. 1848.

[3] Correspondance Astronomique, tom ix. p. 301.

dart out sparks and jets of fire with great rapidity and vivacity. The phenomenon was noticed by other observers.

113. The influence of the atmosphere upon mankind may be negatively considered, granting for sake of argument, that in its absence life could be sustained. Upon the sense of hearing, the want of an atmosphere would be tantamount to its occlusion; for as sound is produced by vibrations in the air, none could possibly exist,—the tongue would *then* be silent, and language unknown,—the organs of smell and vision would no longer serve, or afford us pleasure; for odours would be wanting, and, excepting upon such objects as the sun's rays directly fall, all would be darkness!

.........“ darker than the night.”

CHAPTER VI.

114. Evaporation; dependent on temperature. 115. Latent heat. 116. Dalton's researches; Manoscope. 117. Force of vapour. 118. Dove's theory of the influence of winds upon the tension of vapour in the atmosphere. 119. Humidity. 120. Specific gravity of humid air. 121. Law of vaporic exhalations. 122. General considerations. 123. Hygrometric condition of the atmosphere in elevated regions. 124. Distinction between capacity and quantity; amount of annual evaporation. 125. Cold produced; icy caverns. 126. Dew-point; Mean dryness. 127. How ascertained; range of hygrometer.

114. Upon exposure to the air, a process takes place of conversion of the particle of bodies into the gaseous state. Water at all temperatures assumes the form of vapour. Evaporation proceeds from the snow-clad mountain and the glacier,[1] as well as from the ocean and the meadow. Evaporation differs from vaporization in the amount of heat required for its production. Water *vaporizes* when it passes into *steam*, at a temperature of 212° F. under ordinary pressure; below that temperature, it *evaporates*, passing into the ambient air in insensible moisture, where it is retained till a diminution of temperature renders it apparent,—for Dalton found that the

[1] The evaporation of ice may be experimentally proved. Under the receiver of an air-pump place a saucer containing sulphuric acid, which has a strong affinity for water, and above, a cup partly filled with water. Exhaust the air and evaporation takes place. The acid, by absorbing much of the aqueous vapour, maintains the capacity of the air for moisture, and more of the water is evaporated. The cold becomes great, and the water freezes. If a piece of lint has been put round the water-cup, it will be seen to become covered with an icy crust. The attached barometer now indicates a pressure of less than an inch of mercury. In course of a few minutes the coat of ice disappears, and as the rarefaction is increased, the ice within the cup vanishes.

amount and tension of vapour in the atmosphere is independent of the presence of the air, and wholly regulated by caloric.[1] Hence arise clouds, mists, and other aqueous meteors, when the thermometer falls in a humid atmosphere. In the state of vapour, the moisture exists normally in the form of hollow vesicles, frequently mingled, however, with globules *filled* with water.

115. The first effect which follows the application of caloric is the expansion of the body heated, and this progresses so long as the cause continues; the fluid then assumes the gaseous form,[2] ceasing to manifest to the thermometer its farther ingress, *i.e.* the heat becomes *latent* or insensible: Upon withdrawal of the caloric, the body returns to its pristine condition.

116. Our own Dalton,—the father of the atomic theory, whose memory will be as imperishable as the beautiful system he has propounded,—devoted much of his time to meteorological research. Besides other truths, he demonstrated that the elasticity of water at the boiling point under mean pressure, and that of our atmosphere at the same pressure, are equal; that aqueous vapour possesses exactly the same repulsive force in the atmosphere which it assumes in a vacuum, the temperatures being the same; and that as its elasticity depends upon the increase of heat, so it is possible to ascertain the amount of vapour floating in the air at any temperature, by measuring the elasticity of the aërial fluid. For this purpose, an instrument called the Manoscope[3] has been constructed. According to Gay Lussac, 1000 volumes of air at the freezing point, become 1375 when raised from 32° to 212° F.; consequently, upon each, there is an increase of bulk of 0.375 for 108°, and 0.002083, or 1-480th of its volume, for every degree of Fahrenheit's thermometer. This beautifully simple law applies to all gases: the converse is likewise true; conse-

[1] It is important to bear this constantly in remembrance, for the expression *air saturated with moisture* conveys a false impression, and should be discarded.

[2] Watt estimated the volume of water, and the same quantity converted into vapour at the ordinary atmospheric pressure, as 1 to 1800.—Ph. Tr. 1784, p. 335.

[3] Manometer of Hooke, similar to the Sympiesometer of Adie,—Forbes, Ed. Jour. of Sc. v. x. 334; Ib. N. S. vol. iv. 91, 329.

quently, for the diminution of each degree of Fahrenheit, there will be a condensation of volume amounting to the 1-480th of the mass, if we adopt the numbers of Gay Lussac.[1] Magnus,[2] however, has fixed the rate of expansion at 1–459th of the volume at *zero* ; Regnault,[3] at 1-458th at 0° ; Rudberg, at 1-481st at 0° ; and Dulong and Petit, at 1-448th at 0°,—which is the same with that of Gay Lussac.

117. Dalton reasoned upon evaporation as we do on the *inertia* of matter, and by experimental research discovered in it a conformity with the laws of mechanics. He introduced water into the closed end of a barometer, and applied heat, watching the depression of the mercury from the expansive force of the fluid. Seeing that the atmosphere offers resistance to the diffusion of moisture, till this force is overcome by that of vaporic expansion, Dalton found that the force, or tension, of aqueous vapour,[4]—*i. e.* its power of supporting a column of mercury,—at the temperature of 25° F., equals 0.156 inch. ; at 32° =.2 ; at 35° =.221 ; at 38° =.245 ; at 40° =.263 ; at 42° =.283 ; at 44° =.305 ; at 46° =.327 ; at 48° = .351 ; at 50° =.375 ; at 52° =.401 ; at 54° =.429 ; at 56° =.458 ; at 58° =.49 ; at 60° =.524 ; at 62° =.56 ; at 64° =.597 ; at 66° =.635 ; at 68° =.676 ; at 70° =.721 ; at 73° =.796 ; at 76° =.88 ; at 80° =1.0 ; at 84° =1.114 ; at 90° =1.36 ; at 95° = 1.58 ; at 100° =1.86 ; at 125° =3.79 ; at 145° =6.53 ; at 180° =15.15 ; and at 212° it amounts to 30 inches, or one atmosphere : the grains of water evaporated in the same time are in a similar ratio.

[1] Let 10 cub. in. of air at 45° be raised to the temperature of 60°, then the volume of the same air under the increased heat will equal 10 × (60 + 448 ÷ 45 + 448) = 10.304 cub. in. Hence the formula,

$$v' = v \times \frac{t' + 448}{t + 448}$$

where v represents the gas or air in its original volume, v' its altered capacity ; t = the original temp. ; t' the increased temperature ; and the constant 448 = 480–32.

[2] Poggendorf's Annalen. lv. 1.

[3] Ann. de Chim. et de Phys. 3d ser. iv. 5, and v. 52.

[4] Dalton,—Manch. Mem. vol. v. p. 559 ; Ure,—Ph. Tr. 1818 ; Ann. de Ch. 1830. xliii. 74, where the experiments of the French Commission composed of MM. Arago, Dulong, Ampère, De Prony, and Girard are recorded ; Bulletin Univ. xii. ; Brande's Journ. N.S. viii. 191 ; &c.

In applying this table of vaporic force, let us suppose that the atmospheric temperature is 70°, that the *dew-point,* a term to be presently explained, is found to be 50°, and the barometer 30 in., then the moisture floating in the atmosphere will be equal to the force of vapour at that temperature divided by the barometric pressure, *i.e.* in this instance 0.375 ÷ 30, or 1-80th of its volume,—100 parts of such an atmosphere consisting of 98.75 of dry air, and 1.25 of the vapour of water in an expanded condition. In this case, 29.625 inches of the mercury in the barometer are supported by the dry air, and the remaining fraction 0.375 inch by the aqueous vapour—(*vide* 120). Again, let us suppose the dew-point to be 40° and the barometer 30 in., then the humidity will be 0.263 divided by 30, or about 1-114th of its volume. Let us illustrate this law by another example; if the dew-point be 58°, the vaporic force will be 0.49, and if the barometer stands at 30.5 inches, then the humidity will be a little more than 1-62d of the volume of the air.

118. The tension of vapour, according to Professor Dove, reaches the maximum when the wind is south-west, and declines to the minimum when north-east winds are blowing; it falls on the western, and rises on the opposite side of the windrose. This arises from the repressing influence of currents, cold, dense, and dry, upon the warm humid ones acting on the western side of the compass: the converse is the case on the eastern side. "The S.W. is the equatorial current which has descended through the lower current to the surface of the earth; the N.E. is the polar current prevailing undisturbed."

119. The diffusion of aqueous vapour in the atmosphere is what is meant by its humidity. Various circumstances lead to alterations in this respect, as temperature and the physical features of the locality. The presence of water blended with the air may be experimentally illustrated. Let that fluid be exposed to the air in a closed vessel; speedily a portion will have risen in invisible vapour, and that in proportion to the temperature; now introduce one or other of those salts which easily dissolve or deliquesce on exposure to moisture,—*e.g.* acetate, nitrate, or hydriodate of potass, or iodide of iron,—and

very soon it will assume the liquid form, proving the existence of watery particles in the confined atmosphere.

120. The specific gravity of a humid atmosphere being lower than that of dry air,—because vapour is lighter than air, bulk for bulk,—it follows that the specific gravity of the atmosphere is subject to its humidity. Hence the amount of moisture present may be approximately ascertained by the weight of a cubic foot of air, keeping in mind that a cubic foot of such an atmosphere consists of a cubic foot of dry air and a cubic foot of aqueous moisture, filling the same 1728 cubic inches, and having tensions proportioned to the temperature; but as caloric expands both aqueous vapour and the atmosphere, corrections are required, (*vide* 20). The late Professor Daniell[1] has given a table of the ratio of the expansion and weight of *a cubic foot* of vapour at various temperatures:—Thus, the *expansion* at zero equals 0.9334; at 10°=0.9542; at 20°=0.975; at 30°=0.9959; at 32°=1.0; at 45°=1.027; at 55°=1.0479; at 75°=1.0895; at 95°=1.1312; and at 212°=1.3749: the *weight* at zero equals 0.856 grain; at 10°=1.208; at 20°=1.688; at 30°=2.361; at 32°=2.539; at 45°=3.893; at 50°=4.535; at 55°=5.342; at 60°=6.222; at 70°=8.392; at 75°=9.78; at 95°=17.009; and at 212°=257.218 grains. Let us illustrate this by referring again to an example, (117, page 100). Suppose we have found the dew-point to be 50° F., the atmospheric temperature 70°, and the barometric pressure 30 inches, we wish to know the weight of moisture contained in a cubic foot of such an atmosphere. As 480 volumes at 70° F. become 460 at 50°, so a cubic foot, or 1728 cubic inches, occupies the space of 1656 cubic inches; and if 1728 cubic inches at 50° weigh 4.535 grains, 1656 will weigh 4.345 grains, the weight of aqueous vapour which we desired to ascertain.

121. The quantity of vapour exhaled is greater when the surface is extensive, and this, in proportion to the superficies.[2] Evaporation goes on less speedily in a moist than in a dry air,

[1] Met. Essays.

[2] Halley computed the evaporation from a square degree of ocean to be more than 33 millions of tons daily; consequently, the Mediterranean daily loses in this way 5,280,000,000 tuns of vapour. Ph. Tr. No. 189.

and in cold than in warm temperatures. Perhaps it is not far from truth, to say, that *cæteris paribus* the rate of evaporation is inversely as the air's density ; hence we find the minimum amount during the winter, and the maximum at the opposite season. A given volume of air contains more vapour in the tropics than in the polar regions. Thus, a cubic foot at 100° F. will suspend about 19 grains of water ; while at zero, only the fraction of a grain ; at 80° it will hold in solution about 10 grains, and at 32° only 2.5 ; at 50° there will be found a little more than four grains ; at 40° only three and a fraction, and at 30° about two grains.

122. Upon the Col du Géant, between Courmayeur and Chamouni, Saussure found evaporation proceed more speedily than at Geneva, as 1 to 0.44. The atmosphere over inland districts is less humid than upon seas or by coasts ; less moist over sparingly-cultivated regions than over those which are well wooded, and the minimum occurs in deserts. The influence of winds has been noticed in Europe ; thus the S.W. winds blowing over the Atlantic are remarkably humid, while those from the N.E. are generally dry ; nevertheless, peculiar conformations in the locality may render the latter winds moist, but this is an exception to the law. In India, the maximum humidity occurs during the S.W. monsoon. Dr Davy states that at Colombo in Ceylon, though at a temperature of 82°F., this wind indicates a dryness of 30 degrees ; whilst the N.E. monsoon with a temperature of 68°, has a dryness of 75 hygrometric degrees. In South America, although the air may appear dry, yet from the Andes a haziness is often seen over the Pacific, rising to the height of more than a thousand feet.

123. Humboldt[1] mentions that between the valleys of the Irtysch and Obi in Central Asia, on the steppe of Platowskaia, he, Rose and Ehrenberg, found the dew-point equal 24°, and the temperature of the air 74°.7 F., with an amount of dryness equal to only the 16-100th of the moisture which might have been suspended in air of that temperature. It is generally

[1] Asie Centrale, tom. iii. Cosmos, vol. i. p. 332,—Sab.

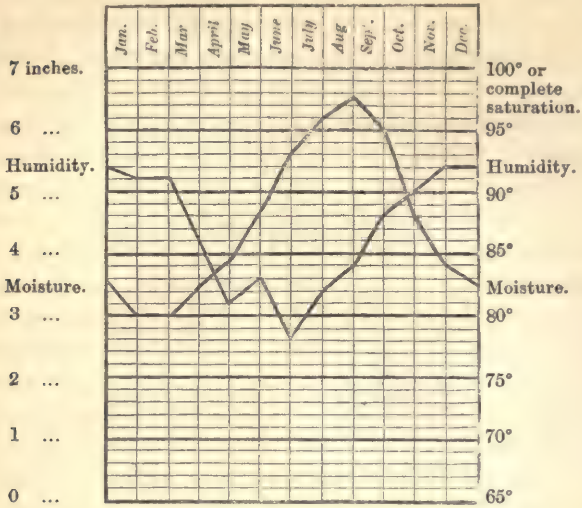
supposed that mountain air is drier than that in the low lands, and the observations of Humboldt in South America, Saussure and Deluc in Switzerland, go far to confirm this opinion ; but Kämtz,[1] from comparison of the air on the comparatively low mountain the Faulhorn, which rises about 8000 feet above the sea, and on the Rigi, with that at Zurich, has collected data from which he arrives at a very different conclusion, the atmosphere at Zurich being charged with only 74.6% of vapour, while that on the Rigi had 84.3%,—the quantities being compared with the gross amount of moisture which at the temperatures of the stations might have been suspended. Martins and Bravais in 1841, made observations tending to the conclusion arrived at by Kämtz. Nevertheless, it is mentioned by Professor Forbes, that when in company with this German meteorologist, they witnessed among the Alps, at an altitude of 8500 feet, "a degree of dryness unexampled in the annals of hygrometry."[2] Farther observations are required for determining the *law* and anomalies of this interesting subject.

124. The atmosphere, we have observed, is more humid during winter than in summer, though, in consequence of the greater capacity of air for moisture through increased temperature, the absolute quantity of vapour is greater during the latter season. The humidity of the atmosphere in this country may be illustrated by the accompanying diagram (page 104), where 100 is supposed to represent the full amount of aqueous particles which the temperature of the air will suspend. The amount of moisture is likewise represented, in the number of inches which it would cover, were the entire elastic vapour precipitated at once upon the earth in the form of rain.

[1] Lehrbuch der Met.; Vorlesungen über Met. 117.

[2] Rep. on Met.—Brit. Assoc. 1832, vol. i. p. 244.

Mean Humidity, and Mean Amount of Moisture in the Atmosphere in this country; the latter computed in the quantity of rain which would fall were it entirely, and at the same time, precipitated.



A current or high wind, by disturbing the equilibrium of the molecules of the air, promotes evaporation. The amount at Cumana, in lat. 10° 25′, with an average temperature of 82° F., equals 100 inches; at Guadaloupe, in lat. 16° 10′ = 97 in.; in the temperate regions with a mean temperature of 52°, = 36.5 in.; at Manchester, = 25.16 in. (Dalton); at Liverpool, from water exposed to wind and sun, = 36.73 in. (average of four years—Dobson)—during June, July and August, the evaporation was three times greater than in November, December, and January. At Kendal, it equals from 18 to 20 in. (5.5 in. were evaporated in 82 days between March and June,—Dalton); at Paris, = 38 inches; and at Cambridge, near Boston, U. S. = 56 in. (seven years' observations).

125. In consequence of the absorption of insensible caloric or latent heat, a depression of temperature takes place during evaporation. This may be shown by moistening the bulb of a delicate thermometer with ether, and turning it rapidly in the air, when it will be observed to fall in proportion to the amount of evaporation. A better illustration is furnished by

an experiment *in vacuo ;* thus mercury may be frozen by the evaporation of ether in the exhausted receiver of an air-pump.[1] It is in consequence of this, that we often experience a smart frost though of short continuance, immediately after a thaw. The icy caverns of the Jura,[2] and the remarkable one mentioned by Sir Roderick Impey Murchison,[3] at Illetzkaya, in the steppes of the Kirghis, near to Orenburg, seem owing to the intense evaporation of moisture, caused by the warm and dry external air. Daniell has shown that, as the pressure of the atmosphere upon the fluid is reduced in an arithmetical progression, the loss of heat by evaporation follows in a geometrical series, and the amount of evaporation is increased. Thus he found that when the barometric pressure was 30.2 inches, the difference of temperature between the atmosphere and that of an evaporating surface was 9 degrees ; it rose to 12° when the barometer fell to 15.1 inches ; became 15° when at 7.5 in. ; 18° when at 3.7 in. ; 21° when at 1.8 in. ; 24°.5 when at 0.9 inch ; and 26° when at 0.4 inch,—twenty minutes elapsing between each observation. By a wise arrangement in nature, a check is given in the surrounding atmosphere to the descent of the thermometer during this process. In the evaporation of a certain bulk of water, every 100th part converted into vapour, would lower the temperature 10° F., did not the ambient air supply caloric which modifies the result. As extreme instances of the frigorific power of speedy evaporation, we would refer to the solidification of carbonic acid gas,[4] and to Boutigny's beautiful experiment of freezing water in an incandescent crucible.[5]

126. The temperature denominated *dew-point*, is that which represents the point at which vapour is deposited upon an object colder than itself. When the dew-point and the atmo-

[1] Marcet,—Nichols. Journ. vol. xxxiv.

[2] Pictet,—Ed. Phil. Jour. vol. viii. No. 15, 1823 ; Bib. Universelle. *Ice-cave of Fondeurle,* in Depart. of Drome, S. E. of France,—Journ. des Mines, vol. xxx. p. 157 ; Ed. Phil. Jour. vol. ii. p. 80. *Ice-cavern in Connecticut,*—Amer. Journ. of Science, vol. iv. p. 174 ; Ed. Ph. Jour., vol. vi. p. 353. Lowe's Mag., Ap. 1846, vol. i. pp. 337–349.

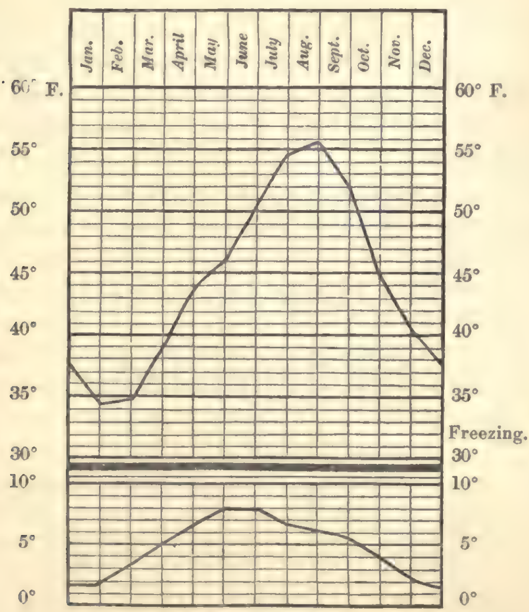
[3] Geol. of Russia by Murchison, Verneuil and Keyserling, 4to, vol. i. p. 198.

[4] Thilorier,—Ann. de Chim. et de Phys. vol. lx. : Kemp in Feb. 1838 in University of Edinburgh.

[5] Brit. Assoc. Cambridge ; Silliman's Amer. Jour. N, S, 1846, vol. i. p. 99.

spheric temperature are the same, the amount of moisture floating in the air is at its maximum, *i. e.*, no more will be suspended without an increase of temperature ; but this does not often occur, the atmosphere being generally a few degrees warmer than the dew-point, and consequently able, either to suspend a larger amount of vapour, or to fall in temperature before the precipitation of that moisture, in a visible form, will take place. The difference between the dew-point and mean diurnal, mensual, or annual temperature is the *mean dryness* of the same respective periods. The *mean dew-point* is always below that of mean temperature, and it is less in January than in August ; whereas the *mean dryness* is greatest in May and June in this country, where the former ranges between 34°.3 and 55°.3 F., and the latter between 1°.6 and 8° F. throughout the year. We give a diagram of the mean dew-point and mean dryness, observed throughout the year.

MEAN DEW-POINT,—ENGLAND.



MEAN DRYNESS.

127. Dalton ascertained the dew-point by the plan of Le Roi. Having filled a *thin* glass vessel with cold spring water, he observed if dew was found upon the outside, and if so, the temperature of the water was too low. Pouring this out and carefully drying the vessel, he replaced it, having allowed it to gain a little heat from the ambient air. Repeating these manipulations till dew *ceased* to be deposited, he marked the temperature of the water at that instant, and thus obtained the required indication. Instruments which we shall hereafter describe, called *Hygrometers*, have been invented for more easily ascertaining the humidity of the air, but when carefully performed, the method described, with the aid of a formula, is the best. When the hygrometer falls below 15°, the air feels *damp;* when ranging between 30° and 40° it is *dry;* when from 50° to 68°, *very dry;* and when above 70°, *intensely dry.* An apartment to be comfortable, should range between 35° and 60° degrees as the extremes. In this climate, it oscillates in winter from 5° to 25°, and in summer, from 15° to 55°. In Upper India it has been noticed so very high as 160 hygrometric degrees. The question whether aqueous vapour is chemically combined or merely blended with the atmosphere, has not been determined—Berzelius, Berthollet, Saussure, and Thomson support the former theory; Dalton, Henry, and author, the latter.[1]

[1] Count Claude Louis Berthollet,—Stat. Chimique; Henry,—Syst. of Chem.; Nicholson's Jour. vols. viii. and ix.; Thomson's Ann. of Philos. vols. vii. and xii. Dalton,—Syst. Chem. Philos; &c.

CHAPTER VII.

CLOUDS.

"I am the daughter of the earth and water,
And the nursling of the sky;
I pass through the pores of the ocean and shores;
I change, but I cannot die.
For after the rain, when, with never a stain,
The pavilion of heaven is bare,
And the winds and sunbeams, with their convex gleams,
Build up the blue dome of air,
I silently laugh at my own cenotaph,
And out of the caverns of rain,
Like a child from the womb, like a ghost from the tomb,
I rise and upbuild it again."

128. Dew is the spontaneous appearance upon objects freely exposed to the atmosphere, of moisture which was invisible. From the remotest ages, an explanation of this meteor has been sought, and poets have often sung its praises. It was early noticed that it was deposited only on nights of cloudless beauty and serenity; hence arose the fancy that it was the produce of the stars, and partaking of such celestial origin, it

is not to be wondered that the most exalted veneration and surprising properties should have been ascribed to it. Aristotle,[1] when he theorized that it was humidity detached in minute particles from the clear chill air, showed that light was gleaming, but soon to be darkened: the human mind was not prepared to receive such a simple truth. Pliny repeats the observation, and tells us that "neque in nube, neque in flatu cadunt rores."[2] Against these rational hypotheses, we would place in apposition the chimera of its telluric rise. The colours from dew-drops have been investigated by Scoresby.[3] To witness the phenomenon, it is necessary to use a telescope of short focus, and turn the back to the sun, taking the shadow of the observer's head as a guide. Varying the position of the instrument, most brilliant globules will be seen, dazzling like diamonds, and shining in all the gorgeous beauty of the spectrum.

129. Dr Wells is our chief authority on dew, and his theory is founded upon calorific radiation. This philosopher paid great attention to the subject, and presented the public with the result of two years' experiments in the vicinity of London, in one of the most beautiful inductive essays in our language.[4] Dr Wells noticed what was pointed out by Dr P. Wilson of Glasgow,[5] that this meteor is deposited on bodies whose temperature is lower than that of the surrounding air; but he correctly assigned a different explanation, having observed that dew does not gather till *after* the temperature of the body is reduced,—that it is the effect, not the cause of the lowering of the temperature of the bodies bedewed. Recently this has been well illustrated by the delicate experiments of Melloni.[6] It is from the invisible elastic vapour diffused around, that the meteor is derived.

130. Analogous to this phenomenon in cause and effect, is the moisture upon the roof and walls of a heated apartment, when the temperature of the humid air within rises above

[1] Meteor. lib. i. cap. x. et De Mundo, cap. iii. [2] Hist. Nat. xviii. 29.
[3] Jameson's Journ. No. 61. [4] Essay on Dew. Lond. 1814.
[5] Ed. Roy. Soc. Tr. 1788—Hoarfrost.
[6] Compt. Rend. No. xiii. p. 531,—Let. to Arago.

that of the building; or upon the windows when a fall of hail or rain suddenly reduces the temperature of the external air; or upon the human body on entering a moist and highly heated hot-house; or upon the walls of rooms when a humid thaw succeeds a protracted frost; or when we breathe upon a cold metallic or silicious substance.

131. We are told by Virgil, Tibullus, Ovid, Lucan, and other ancient writers,[1] of "sweating statues," and weeping images!

> "Et mœstum illacrymat templis ebur, æraque sudant."
> VIRGIL,—*Georg.* i. 479.

> "In temples mourning, Iv'ry wept, and Brass
> Sweated."
> TRAPP.

But what were these? It does not seem a mere poetical licence, but a grave scientific fact,—a fine illustration of the gathering of dew upon bodies colder than the ambient air, which, in the instance quoted, was then intensely humid, for in the same passage, descriptive of the "wonders" seen at Cæsar's death, mention is made of floods which swept woods away and "cattle with their stalls." It is no sufficient objection that the metal figures were also wetted, for though metallic bodies do not speedily receive dew, yet if the circumstances are favourable and sufficiently continued, they will become bedewed. A similar phenomenon was observed in 1506 in Italy.[2]

132. For the deposition of dew the surrounding atmosphere must suspend as much moisture as its particular temperature will allow; and the bodies upon which it falls must be colder than the ambient air. The night must be cloudless, or nearly so, and perfectly serene, with circumstances favourable to terrestrial radiation into the planetary regions: for, according to the theory of Prevost,[3] radiation is always taking place from every object, and consequently when clouds are inter-

[1] Virgil,—Georg. lib. i. v. 479; Tibullus,—Op. lib. ii. 5: Livy,—lib. xliii. cap. 13; Plutarch,—Coriol., &c.

[2] Holinshed.—Chron. v. iii. p. 793, fol.

[3] Rech. sur la Chaleur; Ph. Tr. 1802, 443.

posed, the calorific rays darted from the earth are intercepted and returned, preserving an equilibrium between the ground and surrounding air. Dr Wells[1] never saw dew gather on nights both cloudy and windy. The temperature of the day must be several degrees above that of the night,—and when the difference is greatest *cæteris paribus*, the dew will be most abundant; hence more copious in spring and autumn than during the other seasons. Dr Traill[2] observes, that the dews of Spain and Morocco are far greater than those of Great Britain, though the diurnal temperatures are more uniform there than here; and he explains it by the fact, that in warm climates the increased humidity of the air is in a greater ratio to the increment of heat than in temperate regions. Malcom[3] mentions, that on sailing down the Hoogley in the month of February, the dew which gathered during the night was continually dropping like a smart shower from the rigging. This meteor is not found among the smaller islands of the Pacific, nor in the midst of large seas, but is abundantly deposited near the shores of continents.

133. In the formation of dew upon bodies, we may observe that the amount is much dependent upon the colour of the material. Black glass resists its deposition longer than any other, excepting red, but light, or *cold*-coloured glass, readily receives its particles. The explanation is in the fact, that glass is unequally permiable to caloric, according to its hue.

134. Circumstances continuing favourable for the deposition of dew, Dr Wells observed that its quantity augmented as the night advanced, and it was greater after, than before, midnight; that loose bodies were more affected than such as retain caloric longer, and in proportion to the coldness of the bodies. Hence he found that grass was more abundantly bedewed than garden mould or a gravel walk, and wool or eider down more than grass; also, that it fell more speedily on glass than upon a polished metal. He noticed that it is more abundantly deposited after a misty morning, if the succeeding night is calm and cloudless, or nearly so, and in the morning,

[1] Essay on Dew, 65. [2] Phys. Geography.
[3] Trav. in S. East. Asia,—Burman Emp. ch. i.; Hasselquest,—Trav. p. 455.

if the sky has been previously overcast; that northerly and easterly winds retard, and often prevent its deposition, while southerly and westerly winds are favourable to its formation. Dalton computes the amount of dew which annually falls at five inches.

135. Though Dr Wells explained the degrees in which bodies are bedewed, by the variable amount of radiation from their surfaces,—in other words, their relative temperatures,—other theories of the phenomenon have been given. To electrical influence Saussure and Prevost have ascribed the general absence of dew upon metallic surfaces, while Sir John Leslie attributed it to a repulsive power exerted by them towards aqueous particles. Melloni[1] has recently proved, by simple but beautiful experiments, that it is due entirely to nocturnal radiation, and neither to repulsion of moisture, nor to evaporation on its precipitation on the metallic surface. His experiments at the same time prove, that dew neither ascends from the ground, nor falls from the sky, but separates, as Wells has explained, in visible forms, from invisible moisture in the ambient air.

136. Though dew is much purer than rain, yet the sensible properties of many bodies upon which it falls are often communicated; and other substances resembling dew are sometimes mistaken by the vulgar for this meteor. Kastner[2] found in dew nickel and meteoric iron. The *acid dew*, or *vinegar of Sennagalu*, much esteemed by the luxurious Hindoos, is dew partaking of the properties of the flowering sennaga,—the *Cicer arietinum*. It is collected on muslin, which in the foggy season is spread at sunset over these plants, and removed before the sun's rays have fallen upon them. It is said to contain oxalic, malic, and acetic acids. Dew collected from the leaves of the *Alchemilla vulgaris*, or common lady's mantle, was found by Lampadius to be charged with two per cent. of carbonic acid. *Honey-dew* is a viscous saccharine substance, deposited upon the foliage of certain plants and trees. Mr White, of Selborne,[3] mentions, that in the sultry summer

[1] Compt. Rend. No. xiii.; Phar. Times, v. ii. p. 366. July 10. 1847.
[2] Archiv. v. 190.
[3] Natural Hist. Selborne. lxiv.

of 1783, honey-dew was very abundant. The same was observed in 1847. All agree that honey-dew is not derived from the atmosphere. It is known to be the product of the aphis,[1] and, according to Bevan,[2] is also sometimes exuded from the leaves of certain trees. Sir J. Smith and others mention the perspiration of plants; and Ovid[3] poetically ascribes this product of the poplars of Lombardy to the tears of the Heliades, who, mourning the death of their brother Phæton, were, in heathen mythology, transformed into trees. Of honey-dew Virgil writes, "Aerii mellis cœlestia dona;" and Pliny doubts, "sivi ille est cœli sudor, sive quædam siderum saliva, sive purgantis se aeris succus." *Jelly-dew* is believed to have its origin in a cryptogamic plant,—the *Tremella nostoc* of Linnæus.[4]

137. Hoarfrost, or rime—*gelée blanche,*—is unlike dew only in the congelation of its particles. It is produced under similar circumstances, but the temperature is below that of congelation. The bottoms of valleys, and land-locked places generally, are localities favourable for this meteor, the altitude to which it ascends being determined by temperature. Mountain currents directed downwards prevent its formation on their declivities. Hoarfrost often presents a *spicular* form, the theory of which will be found in the laws of crystallization and peculiarities of the glass upon which it is deposited.[5]

138. Fogs may be divided into *aqueous, dry,* and *luminous.* Aqueous fogs may be subdivided, according to Peltier,[6] into

[1] Boissier de Sauvages observed what Huber confirmed,—that ants suck from the living aphides this nectarious fluid.

[2] The Honey-Bee, &c.

[3] Metamorph. 2.

[4] *Tremella nostoc,*—Lin. Spec. Plant.; Dillenius—De Muscis, tab. x. fig. 14. 53; Gmelin,—Hist. Fucorum, 4to, 1768, 222; Flor. Danica, tab. 885. fig. i. *Tremella intestinalis* vel *mesenterica,*—Lin. Spec. Plant.; Dillenius,—Hist. Musc. tab. x. fig. 16; Flor. Dan. tab. 885. fig. 2. *Tremella meteorica,*—Lin. Syst. Nat. by Gmelin, tom. ii. fol. 1446; Davies,—Welch Botanology. This product is mentioned by Paracelsus, Helmont and others, under the name *Nostoch,* and in belief that it is a kind of *terniabin* or manna. It is described and analysis given by Geoffroy,—Mém. de l'Acad. de Sc. 1708. See also Plot,—Gent. Mag. 1776; Darwin,—Loves of the Plants; Morton's Nat. Hist. of Northamptonshire, 353, &c.; Withering's Brit. Plants, iv. 88. *Yellow Dew.* Ph. Tr. 1695.

[5] Carena,—Sur le Givre figurée, Mém. de Turin. 1813, 1814, pp. 56–79.

[6] Mém. des Sav. Etrang. de l'Acad. de Bruxelles, tom. xv. 2d partie; Elect. Mag. No. 6. p. 416.

H

non-electrical and electrical; and the latter into fogs electrified positively (vitreously), and fogs electrified negatively (resinously). When the atmosphere is humid, and the temperature falls below the dew-point, the moisture becomes visible in the form of a haze, mist, or fog. These terms indicate different degrees of the same phenomenon ;—*haze*, when there is merely an obscuration near the surface of the earth ; *mist*, when it presents a defined outline, resting on, or hovering a few feet above the ground ; *fog*, when the humid vesicles are so numerous as to produce a general obscuration in the atmosphere. The fog, which most frequently appears towards morning or at nightfall, rises much higher than the mist, and has its upper surface generally well defined. The watery particles which give rise to this aqueous meteor may become frozen, and present beautiful icy encrustations upon the objects on which they rest. Fogs occur more frequently at sea than upon land, and by night oftener than during the day. In cold climates, and the polar regions, they are more common than in the warmer zones. In India they appear before and after the rainy season. In Peru there is observed a curious vapour, called *garroua*, "so thick, that the sun seen through them assumes the appearance of the lunar disc. They commence in the morning, and extend over the plains in the form of refreshing fogs, which disappear soon after noon, and are followed by heavy dews, which fall during the night."[1] When moist currents of unequal temperatures meet, the capacity of the air for vapour is changed, and a portion of its moisture deposited in the form described. The banks of Newfoundland are remarkable for a fog which is almost stationary there, arising from the meeting of the cold arctic oceanic current with the warm gulf stream, which communicates to the superincumbent atmosphere dissimilar temperatures. Sea winds often sweep over the southern and eastern coasts of North America, bringing with them dense fogs. A thick fog hovers over the Aleutian Archipelago, in consequence of the melting of the icebergs, and the chilliness com-

[1] Fournet,—An. de Chim. et de Phys.; Ed. Phil. Jour., January 1845; Physical Atlas.

municated to the air, as they float through Behring's Straits southwards to the northern Pacific Ocean.

139. According to Halley, the vesicles of fogs are hollow. From the optical phenomena presented, and explained by Kratzenstein, there seems no reason to doubt the correctness of this opinion. Professor Kämtz gives to these vesicles a mean diameter of 0.0224 millimetre, or nearly 1-1250th of an English inch. He has found that the season influences their size; thus they are twice as large in winter as in summer, the maximum being from December to February inclusive, and the minimum in May and August, the smallest being found in the latter month. The humidity of the atmosphere was observed to modify their magnitude. Drops of water are mingled with these hollow globules.

140. Sir Humphrey Davy,[1] in his theory of mists, explains the phenomenon by the difference of temperature over the land and water, arising from the unequal cooling of their surfaces, and the influence of this diffusion of caloric upon the humid atmosphere. The process of terrestrial radiation advances slowly, and the surface of the earth is the part most speedily deprived of heat. The effect of a reduction of temperature upon the upper stratum of the water is very different: its density is increased, and thereby an upward current of warmer particles established, maintaining a temperature higher than the land. The ambient air is thus warmer over the water than upon the earth, and the moisture which the mean temperature of these dissimilarly-heated airs cannot suspend, is deposited in mist. It will be observed, that in the formation of this meteor, the atmosphere is colder than the ground, while the reverse is the case in that of dew; hence the aqueous particles in the one instance hover over the earth and water, in the other gather upon the ground. Such is the theory of most of our aqueous fogs; but, according to Peltier, it does not account for all. Some of the varieties, he attributes to the electrical state of the earth and higher portions of its atmosphere, or to that of the former exclusively.

[1] Phil. Trans. Royal Soc. Feb. 25. 1819.

141. Thick-driving fogs are generally highly electric. Mr Crosse[1] of Broomfield, thus describes an extraordinary display during such a fog. "I had only 1600 feet of wire insulated at that time, and the glass sticks, *i. e.* the insulating rods at the pole-tops, were streaming with moisture ; so that when I connected a very powerful electrical machine in a high state of action, with the exploring wire, I could not obtain enough electricity to attract the slightest filament of gold leaf. The wind was S.W. accompanied with a steady driving rain and fog during the whole of a November day ; and I found it impossible, by the most delicate condenser, to discover the least symptom of electrical action in the wire. I accordingly gave up experimenting, and commenced reading in the same room ; when after some hours, (the two balls of the apparatus, namely, the giving and receiving one, being at one inch distance from each other,) I heard a smart explosion, and going to the conductor, was highly gratified at a succession of powerful explosions taking place between the two balls, increasing in rapidity until they became one continuous stream of fire, which again diminished in power, and immediately afterwards recommenced with the opposite electricity.[2] These successive changes lasted throughout an interval of *five* hours, during which time the stream given out exceeded in power any I ever witnessed, excepting during a thunder storm. I think the largest animal would have been struck dead if brought into contact with it. This effect was the more surprising, as no apparent change had taken place since the morning ; the same wind, driving fog and rain, the barometer, thermometer, hygrometer, all the same."

A remarkably thick fog was experienced in London and its vicinity, between the 27th December and 2d of January 1814, the thermometer, during its continuance, indicating a

[1] Sidney,—Elect., Rel. Tr. Soc. ; Noad's Elect. p. 94.

[2] Experimentally, the *kind* of electricity, *i. e.* vitreous or *positive*, and resinous or *negative*, may be shown by pointing to a pith-ball electrified, either a stick of wax, or a glass rod. In the former case, the pith-ball will be repelled if negatively electrified, but attracted to the resin if positively charged ; in the latter case, the glass rod will repel the ball when positively, and attract it when negatively electrified. Both methods should be used when there is merely a feeble indication.

maximum temperature of 34° and a minimum of 22°.5 F. There was not a breath of wind while it lasted, but it was dissipated by an east wind on the 3d. The fog condensed upon the trees, grass, and railings, and in St James' Park it dropt in a frozen state from the branches to the depth of an inch. In the metropolis, the smoke of the city became an additional source of discomfort, and candles were required at noon.[1] In Westphalia, there seems to have been a north-east wind, which blew the fog against the trees, where it froze, and by its weight uprooted some three feet in diameter.[2]

142. There is a phenomenon of a very different nature from the humid fog described, to which meteorologists have given the name *dry fog.* It is frequently witnessed in London, Amsterdam, and other large and populous cities, requiring artificial lights to be burned throughout its continuance. The gloom cast around by such a fog has been well expressed in the following lines,—

> "The world was void,
> The populous and the powerful was a lump,
> Seasonless, herbless, treeless, manless, lifeless—
> A lump of death—
> The winds were wither'd in the stagnant air,
> Darkness had no need
> Of aid from them—she was the universe!"
>
> BYRON,—*Darkness.*

Very dense fogs were experienced at Amsterdam in 1790; at Paris[3] on the 12th of November 1797; and at London on the 16th January 1826. Such a fog was witnessed on the celebration of the nativity of our Queen, on the 24th of February 1832, when at noon everything was dark, and at night torches were carried, some quaintly remarking that they were searching for the illumination! This particular species of the dry fog arises from smoke hovering at a low altitude.

But this phenomenon does not always produce such Cimmerian darkness. It is more frequently distinguished by a peculiar muddy appearance of the atmosphere, which deprives

[1] Annals of Philos. vol. iii. 154, and 237; ib. ix. 85.
[2] Gilb. Annalen, lii. 233.
[3] Fourcroy,—Jour. de la Soc. des Phar. de Paris.

the sun of a portion of its brilliancy. In the year 1252, a dry fog gave a red colour to the heavenly bodies for fifteen days together; it was followed by continued drought.[1] In 1348, an awful and portentous fog rose in the east, and stretched over Italy.[2] That year earthquakes rent the ground, and "a pestiferous wind spread so poisonous an odour that many being overpowered by it fell down suddenly and expired in dreadful agonies:"—the plague entered Europe from the east.[3] After a warm summer in 1557, a dry fog occurred, followed by an epidemic. In 1733, such a fog hovered over France, of a most offensive odour.[4] In this country, one was observed in 1755 at the time of the Lisbon earthquake; it lasted eight days. In 1764, one which was followed by storms occurred in France. In 1782, a very remarkable fog appeared in Europe, extending from Lapland to the Mediterranean. It gained its greatest intensity in England, on the 10th of June. Lalande endeavoured to subdue the alarm which had taken possession of the public mind in France.

White[5] mentions a very remarkable one which hovered over this country, from the 23d of June till the 20th of July 1783. It prevailed over the adjoining continent, and produced much fear lest the end of all things was at hand. It appeared first at Copenhagen, on the 29th of May, reached Dijon on the 14th of June, and was perceived in Italy, on the 16th. It was noticed at Spydberg, in Norway, on the 22d, and at Stockholm, two days later; the following day it reached Moscow. On the 23d it was felt on the St Gothard, and at Buda. By the close of that month it entered Syria, and on the 1st of July reached the Altai Mountains in Asia. Before its appearance at these places, the condition of the atmosphere was not similar: for in this country it followed continued rains; in Denmark it succeeded fine weather of some continuance; and in other places it was preceded by high winds. The sun at noon looked rusty-red, reminding one of the lines of Milton,—

[1] Hol. chron. Fol. vol. iii. p. 245. [2] Spangenberg, Chron. ch. 287.

[3] Hecker,—Epidem. Mid. Ages; Comte de Mezeray,—Hist. de France, 1685, tom. ii. p. 418; Deguignes,—Hist. Gén. des Huns. 1758, p. 225.

[4] Jussieu. [5] Nat. Hist. Selb. lxv.

> . . . . "As when the sun, new ris'n,
> Looks thro' the horizontal misty air
> Shorn of his beams; or from behind the moon,
> In dim eclipse, disastrous twilight sheds
> On half the nations, and with fear of change
> Perplexes monarchs."
>
> *Paradise Lost*, i. 594.

The heat was intense during its continuance, and the atmosphere was highly electric. Lightnings were awfully vivid and destructive. In England many deaths arose from this cause, and a great amount of property was lost. In Germany, public edifices were thrown down or consumed by it; and in Hungary, one of the chief northern towns was destroyed by fires caused by the electric fluid, which struck it in nine different places. In France there were extraordinary hailstones and violent winds; in Silesia there were great inundations. The dry fogs of 1782–83 were accompanied by influenza,—at St Petersburgh, 40,000 persons were immediately attacked by it, after the thermometer had suddenly risen 30°. Calabria and Sicily were convulsed with earthquakes; in Iceland a volcano was active, and about the same time, one sprung out of the sea, off Norway. The co-existence of dry fogs with earthquakes and volcanic eruptions had been previously observed, *e. g.* in the years 526, 1348, 1721, and since then in 1822 and 1834.

In 1819 a very striking phenomenon of this kind was observed in North America,[1] to precede a black rain which fell at Montreal. In the House of Representatives the speakers could not distinguish the countenances of the members. A similar obscuration had been observed in the United States in May 1780, after a continuance of dry weather; this darkness lasted only a few hours, while that of 1819 continued several days. In 1831, dry fogs obscured the air, and that year the Asiatic cholera and influenza prevailed. Before the arrival of that awful malady, Dr Prout[2] examined daily the

[1] Ed. Phil. Jour. 1820, vol. ii.; Mem. Amer. Acad. vol. iv. p. 393. See in connection Silliman's Amer. Jour. vol. i. 116, 334; Mem. Amer. Acad. vol. i. 234.

[2] Rep. Brit. Assoc. 1832, 2d ed. p. 570.

weight of our atmosphere, and continued his observations, which were made with great care, till he accumulated 87 results. These experiments were made upon dry air free from carbonic acid gas, the thermometer being 32° F. and the barometer 30 in., and were conducted between the 16th of December 1831 and the 24th of March 1832. Upon the 9th of February he detected a striking increase in its absolute weight, 100 cubic inches, under the circumstances stated, weighing 32.8218 grains. "It is remarkable," says this physician and meteorologist, "that after this period, during the whole time that the experiments were continued, the air almost uniformly possessed a weight above the usual standard; so that the mean of the 42 observations after this crisis, exceeds the mean of the 44 preceding it by no less than 0.0118 gr. How the circumstance is to be explained, it is difficult to form a conjecture; but perhaps it may be worth while to observe, that almost precisely at the period mentioned, the wind veered round to the N. and E., where it continued for a considerable time,[1] and that under these circumstances the epidemic cholera first made its appearance in London. It would seem, therefore, as if some heavy foreign body had been diffused through the lower regions of the atmosphere about this period, and which was, somehow or other, connected with the disease in question."[2]

Upon the 23d of May 1834, Kämtz witnessed a remarkable dry fog, on the Victor among the Hartz Mountains, which passed to Basle by a violent north wind. It remained at the latter place for a few days, till on the 25th a N.E. wind blew it to Orleans; from the 21st to the 24th it was seen at Munster. This meteorologist witnessed others of the same description in July and August, and these were noticed at Halle, Freiberg, and Altenberg. There were then great peat-burnings in Bavaria, in the vicinity of Munster and Hanover, and at the same time conflagrations of extensive forests in

[1] On the 8th and 9th it was S.W., but upon the 10th it changed to N. and N. to N.E. It continued N.E. till the 1st of March, when it veered to S. and for some time afterwards it was S.W.—Athen. 1832.

[2] Rep. Brit. Assoc. 1832, p. 572.

Silesia, Sweden, Prussia, and Russia. In the early part of 1846, dry fogs traversed the earth from S.W. to N.E.[1] In Scotland they were characterised by an offensive odour. About the close of 1847, dry fogs were noticed while influenza was epidemic. A few days after the remarkable depression of the barometer, which was witnessed upon the 7th of December, the author was five hours in sailing down the Clyde, from Glasgow to Greenock, in consequence of such a fog.

143. The cause of these dry fogs is still obscure. Finki attributes those which are often met with in Holland and Germany to peat-smoke. Veltmann explains the remarkable phenomenon of 1783, by the smoke which arose from the peat-burnings in Westphalia; and to this, Kämtz[2] adds the carbonaceous evolutions from the scorching influence of volcanic lava. The American fog of 1819, which terminated in a *black rain*, might arise from the burning of a prairie. We have mentioned the co-existence of extensive fires upon the continent with the phenomena of 1834, and Kämtz assigns this, as their origin.

The intimate connexion of dry fogs with epidemics, indicates either a common origin, or points to the one as the cause of the other. The simultaneous appearance of volcanic eruptions, and other terrestrial convulsions,—although these are not universal attendants,—demands attentive consideration. Dr Prout[3] has directed attention to the probable existence of seleniuretted hydrogen[4] in the atmosphere at these times. This gas, which was discovered by the late Baron Berzelius, "produces remarkable effects on the organs of respiration; when the *smallest bubble* of it is admitted into the nostrils, it excites pain, and destroys for some hours the sense of smell, followed by catarrh, deep pain of the chest, and expectoration of mucus, which continues for several days."[5] Selenium is known to be a volcanic product, and is not an uncommon

[1] Gardeners' Chronicle. [2] Meteorology.

[3] Bridgewater Treatise.

[4] Or *hydroselenic acid* = 1 eq. of selenium + 1 eq. of hydrogen.

[5] Fyfe's Chem. p. 326; Ann. of Philos. vol. xii. p. 14. xiv. p. 101; Ann. de Chimie, tom. ix.; Turner's Chem. 8th Ed. p. 332.

attendant of sulphur;[1] it is possible, therefore, that during these terrestrial disturbances this metal combined with hydrogen, or, as Dr Prout observes, with hydrogen and ammonia, mingles with the air, causing those diseases which are then epidemic.

144. Some singular coloured and luminous fogs have been observed. Under the influence of such a medium, near Melrose, the sun assumed a salmon colour, on the 13th September 1824, from 2 to 5.5 P.M., and in the evening the moon shone with the same appearance; at 11 P.M. a storm of wind arose.[2] Howard notices several which came under his observation: thus, two of a rose hue, seen in the west in the months of March and June; one of an indigo-blue, passing into opaque white below, and transparent red above, seen in the month of January; another of a thin brownish-red, in May; and another, which gave the sun a bluish colour from 9 A. M. till noon, seen in Sussex, Essex, Worcester, and in London. Rozet[3] mentions that the remarkable fog of July and August 1831, observed even in North America, shed a blue light on surrounding objects off Algiers, on the 3d of the latter month.

At new moon in 1743, a fog appeared at night, so luminous, that objects 200 yards distant could be observed. Such a mist was seen by Sabine, in August 1836, at Loch Scavig in the Isle of Skye. It rested upon the summit and the upper portion of a mountain rising nearly 2000 feet above the sea. At night the mist was distinctly luminous, but so thin as to allow the contour of the mountain to be visible. At 9 A.M., what seemed to be auroral beams ascended from it about 10° towards the zenith, and continued to do so for nearly an hour. Gisler mentions a phenomenon of this kind in Scandinavia. These luminous fogs are supposed to be magnetic. There is a fog of a different nature still, witnessed in the Atlantic at the Cape de Verd Islands, producing a haziness in the atmosphere. Ehrenberg examined the cause of this, and found it to arise from innumerable siliceous infusory animals. May

[1] Pleischl,—Ann. of Philos. vol. xxiv. p. 230; Stromeyer,—Ib. p. 156, and vol. xxvi. p. 234.
[2] Ed. Jour. of Sc. vol. ii. p. 173.
[3] Voy. dans l'Alger.; Arago,—Annuaire pour 1832.

not these occasionally be phosphorescent, and give luminosity to mists?

145. There is a fog in the polar regions, termed *frost-smoke* by the voyagers by whom it is described. It rises from the ocean, to the height of about two degrees, on the approach of winter; and is caused by the evaporation from the water, in consequence of the lower atmosphere being colder than the surface of the ocean.[1] The sea "steams like a lime-kiln" till, through the intensity of the cold, it is locked by a sheet of ice. Sir Charles Giesecké, who resided several years in Greenland, observes, that the frost smoke "frequently raises blisters on the face and hands, and is very pernicious to the health. It produces the sensation of needles pricking the skin."

146. Clouds differ from fogs in their altitude and suspension, but in composition they are alike, having the ultimate constituents of water for their ingredients. The proximate cause of their formation is the loss of caloric in the humid atmosphere, and condensation of the moisture; but we are still ignorant of the ultimate cause of the phenomenon. Of their mode of suspension, their specific gravity being lighter than that of air, some have received this as a satisfactory explanation, but it is far from being cogent. Professor Stevelly[2] of Belfast, offers a theory combining the gravitating force of the vesicles,—which through their extreme minuteness is exceedingly trifling, for the weight decreases directly as the cube of the radius,—with an electrical hypothesis to be immediately referred to. A far more plausible theory than the first, attributes it to currents,—upward[3] and horizontal. Another hypothesis assigns it entirely to electrical agency.[4] We know that electricity has much to do with the phenomenon; it is largely developed during evaporation, as was long ago shewn by Volta, Saussure, Lavoisier, Laplace, and Bennet,[5] and the vapour acquires that form denominated *positive*, while the water which remains is *negatively* charged—terms arbi-

[1] See Paul Egede,—Hist. of Greenland.
[2] Brit. Assoc.; Athen. 1834, p, 713.
[3] Gay-Lussac,—Ann. de Chimie, tom. p. 59.
[4] Luke Howard.
[5] Ph. Tr. 1787.

trary but convenient, indicating *one* electricity in one or other of its separate conditions.

That clouds are often largely charged with one of the forms of electricity is abundantly manifest. Canton observed this, and found that the electricity would alternately change from positive to negative, five or six times in 30 minutes; which Crosse has confirmed. Why certain clouds should be positively, and others negatively charged, is not yet determined, though the fact is incontestable. Mr Luke Howard has proved that the electricity of the nimbus cloud, is positive internally and negative at the circumference. Baron Humboldt had many opportunities of corroborating the curious observation of Tralles, that in the neighbourhood of waterfalls, even at the distance of 400 feet, the electrometer indicates the presence of negative electricity, arising doubtless from the minute vesicles of water in the air. In whichever state, then, the electricity exists in the aggregate, there will be a repulsion and attraction of the particles, by virtue of the law, that bodies similarly electrified repel, while those in the opposite electric states attract each other. As the temperature of the vapour decreases, and the humidity becomes condensed, its capacity for electricity lessens and a portion separates. It is easy to conceive that this electricity accumulates around the individual molecules, and prevents the coalescence of the vesicles into drops, the specific gravity of which would cause their precipitation. Thus they are buoyed in the air till other influences cause their descent.

147. According to Peltier, clouds of a slate-grey colour are charged negatively, while those of a rose, white, or orange hue, are positively electrified. These tints, he supposes, change with a corresponding alteration in the character of the electricity of the cloud. Instances are not wanting of clouds appearing of a copper-colour during thunder-storms, and communicating the same lurid glare and metallic lustre to surrounding objects. On the 12th of September 1817, at Engheim, a thunder-storm was preceded by dense dark clouds which covered half the sky, coloured of a dull copper hue; the reflected light gave a metallic tinge to the streets and houses, so that

every thing seemed as if made of copper.[1] A similar phenomenon was witnessed during a thunder-storm in Berwickshire.[2]

148. Having referred to the singular appearance of *green clouds* (*vide* 90), we would quote from Bishop Heber[3] the description which he has given of a phenomenon of this kind, witnessed by him in India. "This evening—18th September 1823—we had a most beautiful sunset, the most remarkable recollected by any of the officers or passengers, and I think the most magnificent spectacle I ever saw. Besides the usual beautiful tints of crimson, flame-colour, &c., all which the clouds displayed, and which were strongly contrasted with the deep blue of the sea, and the lighter but equally beautiful blue of the sky, there were in the immediate neighbourhood of the sinking sun, and for some time after his disc had disappeared, large tracks of a pale translucent green, such as I had never seen before, except in a prism, and surpassing every effect of paint, or glass, or gem. Every body on board was touched and awed by the glory of the scene; and many observed that such a spectacle alone was worth the whole voyage from England." Mr Lind[4] noticed a similar phenomenon in July 1826, at Patna:—"The sky at sunset of the 6th presented a beautiful appearance, clouds of bright green (portending rain), being surrounded with others coloured scarlet. At night, coronæ formed round the planets and large stars, and on the 8th 2.249 inches of rain fell."

149. Thunder clouds generally float at altitudes of from 3000 to 5000 feet, though they have been seen so high as 15,000. Clouds have been observed over the summit of Chimborazo, at an altitude of about 21,500 feet. In proportion to their lightness, they will generally be found suspended higher in the atmosphere; the lightest of all, viz. the cirri, occupying the loftiest strata of the cloudy region.[5]

150. The motion and velocity of clouds depend generally upon one and the same cause, operating in different degrees

[1] Dr P. Neill,—Jour. of Tour by Dep. of Caledon. Hort. Soc. p. 329.

[2] Ed. Phil. Jour. vol. viii. 387; Jameson,—Werner. Soc. Jan. 25. 1823.

[3] Jour. ch. i.

[4] Ed. Jour. of Sc. vol. viii. p. 249.

[5] Whewell,—Br. Assoc. Southampt. 1846; Kämtz,—Lehrb. der Met. tom. i. p. 385; Martins,—Leçons de Met.; Compt. Rend. tom. xi. p. 324, 1840.

of intensity. Atmospheric currents and electricity are the moving powers. Both together may exert an influence in the same or opposite directions. Hence we may find clouds floating in various paths, crossing, meeting, uniting, increasing, diminishing, or disappearing. The direction of the impelling currents is not always indicated by the path of the cloud; for should two of equal force be moving in opposite tracks, the cloud will appear at rest; should they blow at right angles, the motion of the cloud will be diagonal, in obedience to the laws of mechanics. Mr Foster, on the 25th of October 1809, sent up a small balloon at Clapton, while a gentle but variable breeze was blowing upon the earth. At different heights the presence of four currents was manifested,—beginning with the lowest,—from the E.N.E.; N.; S.W.; and S.S.E. The next day he repeated the experiment, when three currents were detected,—E. N. E.; S. E.; and S. S.W. The longest duration of constant currents which we know of, occurred in 1781, during the Dutch war. A large fleet had sheltered in the Frith of Forth for above a month, the wind being easterly and brisk; during the latter half of that period, a constant westerly current was indicated by clouds, at an elevation of three-quarters of a mile. Opposing currents are met with even in the region of the trade winds, as we shall hereafter explain. Thus Mr Bennet[1] mentions having seen three strata of clouds in those winds, the lowest and the highest moving in the direction of the trades, while the intermediate one was progressing in a path directly opposite. Another illustration may be given,—on the 22d–23d January 1835, a volcanic eruption took place near San Vincent in South America, and on the 24th–25th of February the fine ashes ejected reached Jamaica, where they fell in a dust-shower, after being carried E.N.E. at the rate of thirty miles a-day, in a direction almost precisely contrary to that of the trade winds.

151. Seeing that the earth is ever radiating caloric, and that the clouds diminish the loss by returning a portion of the heat, the correctness of the observation of Lord Bacon[2] will be apparent,—"Star-light nights, yea, and bright moon-

[1] Tyerman and Bennet's Journ., vol. i. p. 50. [2] Nat. Hist. § 866.

shine nights, are colder than cloudy nights." We find that their presence during the day even influences the temperature: in summer they tend to depress the thermometer, while in winter they slightly elevate that instrument.

152. A simple and efficient nomenclature has been devised by Howard,[1] who divides clouds into seven species,—the cirrus, cumulus, stratus, cirro-cumulus, cirro-stratus, the cumulo-stratus, and nimbus. It will be observed that, excluding the last, these species resolve themselves into three simple and three compound forms; besides which, Kämtz describes an eighth,—the strato-cumulus.

The *Cirrus*, or curl cloud, resembles a lock of hair: it is composed of fibres lying parallel,—generally pointing S.W. and N.E. or S. and N.,—bending or diverging. Its pencillings are white upon an azure ground, and it frequently appears when those of another species are floating below. It has been subdivided into linear cirri, reticular cirri, and comoid cirri, or "grey-mare's tail," the wind-trees or *windsbœume* of the Germans. It generally indicates a breeze, or is the precursor of a storm, the wind blowing from the point to which the delicate fringe-like fibres are directed. Floating in the highest regions of clouds, at an altitude where the temperature is below 32° F., it is supposed to be formed of frozen particles. Through it, the finer luminous meteors, *e. g.* parhelia and solar halos, often appear. The transition to cirro-cumuli or cirro-strati is frequently observed.

The *Cumulus*, stacken cloud, "day cloud," or "balls of cotton" cloud, is dense, convex or conical, floating near the earth, increasing from above, and rising upwards as the day advances, to fall again as it declines. Often it towers to gigantic size and looks like a mountain range clad in snow. The form it assumes, Saussure observes, is owing to the mode of its formation. The deep blue of the sky seen between the intervening spaces, forms a lovely contrast with its snow-white heaps. It is a morning cloud increasing towards noon, and gaining its maximum at the warmest period of the day.

[1] Climate of London; see Karl Fritsch,—Ueber die Periodischen Erscheinungen am Wolkenhimmel. Prague, 1846.

With the setting sun it generally disperses, foretelling settled weather; but should it continue, and pass to the state of cumulo-stratus, the atmosphere is very humid and rain will fall. In the hot summer months this cloud is particularly grateful, by interposing itself between the earth and ardent sun, reminding us of the words of Job, "with clouds he covereth the light; and commandeth it not to shine by the cloud that cometh betwixt," (chap. xxxvi. 32). Cumuli are formed of vesicular vapour carried by the upward currents into the colder regions, where the moisture is condensed.

The *Stratus* or Fall-cloud, as its name implies, is an extended, continuous, level sheet, increasing from beneath. It rises in the calm of evening from the river or the lake, creeps along the ground, and hovers over the hill-top. The day which is heralded by the stratus melting away in the rising sun, will be delightfully serene.

The *Cirro-cumulus*, sonder-cloud, or fleecy cloud, is a series of small roundish clouds in close proximity or in contact. It is a dense cloud, composed of aqueous vesicles, and exists at various altitudes. In winter it is fleeting; and it occurs between the fall of summer showers. Lunar coronæ are often met with in this cloud. A curious and important connexion has lately been shewn by Humboldt, Arago, Thienemann, Franklin, Parry, Richardson, Wrangel, Kämtz, Martins, and Bravais, between the cirri and the cirri-strati,—the "polar bands" of Humboldt,—and the aurora-borealis, which is now believed to be a magnetic phenomenon. May these lofty clouds not arise from magnetic precipitations, is the question which flows from their inquiries.

The *Cirro-stratus*, or wane-cloud, lies nearly horizontal, is attenuated at the circumference, concave downwards or undulatory; it may occur in groups, and is more dense than the cirrus. It often changes its form, rising on summer evenings to a considerable height. It is a rainy cloud. When near the zenith, it seems as if made up of many thin clouds; and in the horizon it appears in perspective as a long slender band. When interposed between the earth and the heavenly bodies it occasions halos. It has been subdivided into the

mottled cirro-stratus cloud, and cymoid-cirrus, the latter being a variety of the cirro-stratus composed of waving bars or streaks. In approaching the earth it may descend in a dense drenching mist, and it often forms the mountain-cap.

The *Cumulo-stratus*, or twain-cloud, is a mixture of all the others. It is the cumulus mingled with the cirro-stratus, or cirro-cumulus ; flattened at top and overhanging below. It blends the whiteness of the cumulus with the often dark streaks of the stratus. It prognosticates a lowering day, if rain does not fall. Its oft-threatening size and strange contorted form warn us of thunder.

The *Nimbus*, or rain-cloud, is a dense cloud passing beneath into a shower. It is rain in profile. The azure sky may be visible in the zenith, cumulo-strati seen gathering below, and the grey nimbus in the horizon, darkening the landscape upon which it is shedding down its waters,—a flash darts from its portentous mass, and the rolling thunder strikes terror in the animate creation.

The *Strato-cumulus* cloud has a strong analogy to those whose names it bears, dense and rounded like the one, and extensive as the other. It is an evening cloud, forming after the sun has begun to decline and replacing the true cumulus, but occupying a position higher than the stratus. It may cover the sky entirely during the night, and not disappear till some hours after sunrise. In winter it sometimes conceals the sky for days together.

153. It must not be forgotten that the elevation of the cloud and the angle of observation, produce a very different effect from that which accompanies the meteor when seen overhead ; consequently the same cloud, crossing from the horizon to the zenith, appears to pass through many phases.

154. The attentive observer not unfrequently witnesses the metamorphoses of the clouds. Thus, an evening mist may become a stratus cloud, which under the heat-giving influence of the sun is dispersed ; the day becomes warmer, and vertical currents carry the humid particles into a colder region of the atmosphere, where they are again seen in the cumulus ; ascending higher they are transformed into cumulo-strati, cirro-strati, and finally, into cirri. On the other hand, cirri may

first catch the observer's eye; these may be transformed into those which are more dense, till at last the storm-cloud darkens the sky and they are dissipated in rain. Cirri form under the influence of horizontal currents, and from their lofty position preserve longest the same track; those which are met with lower down, veer about with erratic winds and are less steady in their course. In this country clouds are almost always present, but in the month of May 1848, the sky was cloudless, both night and day, during the first eight days, and almost free of them till the 15th, no haze even existing in the atmosphere during that period—"circumstances without a parallel on record."[1]

155. When a humid current sweeps across the plain and rolls up the mountain side, it loses a portion of its caloric; consequently the air, which before suspended aqueous vapour in the condition of its maximum density for the particular temperature of the aerial stream, parts with moisture proportionate to the loss of heat, and this becomes condensed around the summit of the hill. Such is the most simple explanation of the *mountain-cap*. This cloud does not always rest *upon* the mountain, which may be owing to the centrifugal force communicated to the air in its passage, thereby leaving an intervening space occupied by an atmosphere warmer and comparatively motionless. The current having cleared the summit, progresses onwards, receiving an accession of heat as it descends, and the moisture which had become apparent is again dissipated; but the cap continues, because the place of the former vapour is supplied by other portions of the atmospheric current, which in their turn—

"Pause to repose themselves in passing by."

Sometimes two caps are seen, one above the other, each presenting an exact contour of the mountain, *e. g.* on the Puy de Dome.[2] Occasionally the phenomenon is presented in the form of a ring, wreathing and curling round the hill top; and at other times, in that of a tabular mist, *e. g.* the "table-cloth" of Table Mountain at the Cape of Good Hope.[3] We observe

[1] Glaisher,—Reg. Gen. Quart. Rep. [2] M. le Cocq of Auvergne.
[3] Arnott's Physics.

a curious effect produced by the presence of a mountain range in some of the islands in the Pacific, where for months together the wind blows in the same direction. In Celebes and Sumatra, for example, where a lofty range extends nearly north and south at right angles to the winds, we find that on the windward side there are tempests, while on the lee side a genial climate enables the inhabitants to gather in their crops. When the wind changes to the other side of the island, a corresponding alteration in the season takes place; it is now serene where before it rained, and the expectations of the people are realized. The wisdom and goodness of God extend through all His works—

> "So reads he Nature, whom the lamp of truth
> "Illuminates." COWPER,—*Task, Book V.*

The presence of the meteors which we have been describing, in their ever-varying form, adds an unspeakable charm to the landscape beauties of our country. The sky of Italy may be lovely in its serenity, and pleasing in its warmth, but it has not the grandeur which ours sometimes assumes, nor can it boast the picturesque effect of that of northern climes. Many of the finest images of Ossian have been taken from these transient vapours, nor can we draw a more striking picture of the sublimity of a scene by no means uncommon, than in the inimitable words of Foster[1]:—"Have just seen the moon rise, and wish the image to be eternal. I never beheld her in so much character, nor with so much sentiment, all these thirty years that I have lived. Emerging from a dark mountain of clouds, she appeared in a dim sky, which gave a sombre tinge to her most majestic aspect. It seemed an aspect of solemn, retiring severity, which had long forgotten to smile; the aspect of a being which had no sympathies with this world —of a being totally regardless of notice, and having long since, with a gloomy dignity, resigned the hope of doing any good, yet proceeding, with composed, unchangeable self-determination to fulfil her destiny, and even now looking over the world at its accomplishment."

[1] Life and Correspondence of the Rev. John Foster, vol. i. p. 211.

CHAPTER VIII.

Κύριος τὸν κατακλυσμὸν κατοικιεῖ. Psa. xxix. 10.

" A common mind perceiveth not beyond his eyes and ears."
TUPPER,—*Prov. Philos.*

156. When the air can no longer retain the moisture blended with its particles, it descends in drops upon the earth, purifying the atmosphere through which they fall, and fertilizing the ground with refreshing rain. This or melted snow is the purest of natural waters, though, in consequence of its solvent power, it generally contains some extraneous ingredients. When pure, it is found to contain an equivalent of hydrogen, and one of oxygen ; consequently it is a chemical compound whose atomic weight (in this country) is represented by $1 + 8.013 = 9.013$, *i. e.* the combining proportions of these gases are in the ratio of 1 to 8. Its composition may be shown either by analysis or synthesis. By the former, it is decomposed into its respective gases in the relative weights

mentioned, or by *volumes* into 2 of hydrogen and 1 of oxygen; by the latter, it is produced when these gases are mixed in the proportions stated and an electric spark transmitted. Under ordinary circumstances, it becomes solid at the temperature of, and under, 32° F., and boils at 212° F.; its greatest natural density is at 39°.38 F.,—Berzelius[1], or 39°.5 F.,—Hope[2]. It is entirely neutral, having neither acid nor alkaline reactions.

157. The amount of rain, or meteoric water, which falls upon the ground is greatest in the tropics, and decreases as we approach the poles. The physical features of the locality influence considerably the quantity. When we say, so much rain has fallen in a given time, we mean the gross amount which has descended upon the earth during that period, making no allowance for absorption or evaporation; it is, in fact, the quantity which would have accumulated on the earth had these agents not diminished the amount. Care must be taken regarding the position of the instrument with which the quantity is measured, both as respects the openness of the exposure, its freedom from currents which would induce an unequal collection of the rain-drops, and the height above the ground.[3] Thus, a rain-gauge on York Minster roof gave 14.963 in. between Feb. 1833 and Feb. 1834, while on the ground a similar apparatus indicated a fall of 25.706 inches, and one on the top of the Museum furnished 19.852 inches. The altitude of the first and last stations is 212.87 feet, and 43.66 feet respectively. Again, Professor Phillips[4], with four instruments, placed on the ground, three, six, and twelve feet above its surface, found the following results in a period of four months, 8.408, 8.314, 8.249, and 8.206 inches respectively.

158. The mean annual fall of rain at Sincapore, in lat. 1° 17′, equals 190 inches; at Santa Fe de Bogota, lat. 4° 36′ = 39.4 in., at an altitude of 8684 feet, and mean temp. 58°F.,—Caldas; and at Marmato, lat. 5° 27′ = 64 in., at an altitude of 4674 feet, and mean temp. 68°.7 F., from an average of

[1] Tr. de Chim; 39° F. Blagden,—Ph. Tr. 1792; 39°.39 F. Hallestrōm,—Ann. de Ch. et Phys. xxviii. 90. [2] Ed. Roy. Soc. Tr. vol. v. p. 379.

[3] Lord Charles Cavendish, and Dr Heberden,—Phil. Tr. lxix.

[4] Brit. Assoc. 1840.

years 1843–44,—Boussingault.[1] On the coast of Malabar, in lat. 11° 5′=123.5 in.; at Tellicherry, lat. 11° 50′=116 in.; in the Island of Granada, lat. 12° 8′=126 in.; at Matouba, Guadaloupe, N. lat. 16°=285.75 in.;[2] at Kingston, lat. 17° 57′ =83 in.; at Isle of St Domingo, lat. 17° 57′=83 in.; at Mahabaleshwar, Western Ghauts, N. lat. 18°=301.5 in.;[3] at Bombay, lat. 18° 55′=82 in., twelve years' observations; at Vera Cruz, lat. 20°=63.8 in.; in Cuba, lat 21° 50′=141.7 in., 1821; at Calcutta, lat. 22° 41′=81 in.; at Benares, lat. 25° 23′=46 in.; and on the Nhilgerrie Hills in India, lying between N. lat. 10° and 11°, at an altitude of 8500 feet=63.88 inches. At Charleston, South Carolina, lat. 32° 46′=54 in.; at Charleston, ten years previous to 1807,=49.3 in.; at Williamsburgh, Virginia, lat. 37° 13′=47 in.,—Jefferson; at Philadelphia, lat. 39° 57′=30 in.,—Rush; and in the district near Philadelphia, = 47 in., during ten years' observations,—Darlington.[4] At Coimbra, in the Vale of Mondego, Portugal, lat. 40° 13′, on the western side of a lofty mountain range, during two years' observations,=225 in., but this must be above the general average; on the table land of Castile,=10 inches. At Rome, lat. 41° 55′=38.5 in.; at Rutland, Vermont, lat 43° 40′=41 in.,—Williams; at Viviers, in lat. 44° 27′, during forty years,=33.97 in.; on the Great St Bernard, =60 in., during twelve years' observations; at Geneva, lat. 46° 12′=30.7 in., the mean of thirty-two years; at Paris, lat. 48° 50′=20 in.; at Plymouth, lat. 50° 23′=44 in.; at Dover, lat. 51° 7′=37.5 inches.

The fall of rain at Greenwich, in lat. 51° 28′, equalled 24.13 inches in the year 1845. At the same place there fell, during the months of April, May, and June 1848, 7.3 in., which is 2.9 in. above the average fall during the same months in seven preceding years; the total fall, during the six months, January to June, same year, amounted to 15.2 inches, which is nearly 6 inches above the mean of same months in seven preceding years. So large a fall as 7.3 inches in the second

[1] Econ. Rurale, tom. ii. 693.
[2] Johnston's Physical Atlas,—Fol. Edinburgh. [3] Ibid.
[4] Silliman's Journal.

quarter of the year, has not occurred at Greenwich since 1824; and so large a fall as 15.2 in. in six months has not taken place within the preceding thirty-three years, "probably not within this century."[1] At London, lat. 51° 31′ = 24.9 in., from 1812 to 1827,—Howard; at Epping, in Essex, lat. 51° 43′ = 23.65 in.; at Hereford, lat 52° 29′ = 26 in.; at Birmingham, lat. 52° 29′ = 26 in.; at Derby, lat. 52° 56′ = 24 in.; at Retford, Notts, lat. 53° 39′ = 25.78 in.; at Liverpool, lat. 53° 23′ = 33.3 in; at Manchester, lat. 53° 29′ = 36.14 inches. During the four last months of 1824, the rain which fell at Manchester amounted to 25.581 inches![2] In September, so great was the fall of rain that the bog at Keighley in Yorkshire was burst.[3] Similar calamities are recorded, *e. g.* the bursting of the peat-bogs in Sligo, in January 1831, and the Solway-moss in December 1772.[4] At Douglas, Isle of Man, lat. 54°, it equals 37.28 in.; at Lancaster, lat. 54° 3′ = 40 in.; at Kendal, lat. 54° 10′ = 60 in. In the Lake district, in 1845, at Seathwaite, = 151.87 in.; Gatesgarth, = 124.13 in.; Wasdale, = 109.55 in.; Langdale, *from June*, = 92.62 in.; and at Grasmere, = 121 in.,—J. F. Miller, Esq.; at Whitehaven, lat. 54° 33′ = 52 in.; and at Carlisle, lat. 54° 54′ = 34 inches. At Dumfries, lat. 55° 5′ = 36.9 in.; at Largs, on coast of Ayr, lat. 55° 49′ = 43.5 in.; at Castle Toward, Argyle, lat. 55° 50′ = 56 in.; at Glasgow, lat. 55° 52′ = 33 in.; and at Dalkeith, near Edinburgh, lat. 55° 54′ = 25 inches. At Edinburgh, lat. 55° 57′ = 24 in.; during 1846, it equalled 30.5 in., which was 4 inches more than in 1845, and 5.33 above that of the ten previous years,—Dr Stark; at Glencorse, between the double range of Pentland Hills to the south of Edinburgh, where the Crawley springs which supply that city are situated, between 1831–1845, both inclusive, = 548 in., the maximum = 49 in. occurred in 1836, and the minimum = 25 in. in 1842; the mean fall of eleven years, from 1831 to 1842, = 36 inches. At Greenock, lat. 55° 57′ = 39 in.; at Loch Lomond, lat. 56° 10′ = 52 in.; at Aberdeen lat. 57° 8′ = 28.66 in. in 1829, 30.60 in. in 1830; at Fochabers, lat. 57.37′ = 26 in., from observation of seven years; and at Elgin, lat.

[1] Glaisher,—Reg. Gen. Quart. Report.
[2] Dalton.
[3] Ed. Jour. of Sc. v. iii. 54.
[4] Lyell's Geology.

57° 39′ = 24 inches. At St Petersburgh, lat. 59° 54′ = 16.5 in.; at Upsala, lat. 59° 54′ = 16 in.; at Bergen, Norway, lat. 60° 23′ = 88 in.; and at Uleaborg, lat. 65° = 13.5 in. Baron Humboldt mentions, on the authority of M. Pereira Lago, that 280.72 inches fell in 1821, at San Luis de Maranhoe, in Brazil.

159. In the results given, we have followed the order of increments of latitude, irrespective of continent or kingdom. A striking difference is thus observed between the annual fall of rain at Kingston, Jamaica, and St Domingo, both in the West Indies; between Bombay and the coast of Malabar, though separated only about 500 miles; between Coimbra in Portugal and the table-land of Spain; between Paris and the Great St Bernard; between Liverpool and Kendal; Glasgow and Greenock; Edinburgh and Lancaster; and between Upsala in Sweden and Bergen in Norway,—differences which arise from the physical peculiarities of the localities. To the same cause must be ascribed the differences on the opposite coasts of Great Britain; and to this, together with prevailing winds, the seasonal peculiarities. Independent of anomalies, we observe that the amount of rain diminishes as we recede from the equator.[1] This fact has led meteorologists to divide our globe into *hyetographic* regions.[2] Thus, between the tropics of Cancer and Capricorn we have a zone of *periodic rains*, and external on either side, zones of *constant precipitations*. Professor Schouw of Copenhagen has divided Europe and Africa between the equator and N. lat. 60°, into the following regions of seasonal rains:—zone of summer rains, between equator and N. lat. 15°; zone without rains, between N. lat. 15°–30°; zone of winter rains, between N. lat. 30°–45°; and zone of continued rains, between N. lat. 45°–60°. In that truly splendid work, the Physical Atlas, we find the following divisions:—District of *winter rains:* lying north of the rainless district of Africa, and including the Madeiras, north of Africa, south of Spain and Portugal, Sicily, south of Italy, Greece, and north-west of Asia. The district of *autumn*

[1] Arago,—Ann. du Bur. des Long. 1824, 1825; Annal. de Ch. xlii. 360.

[2] Physical Atlas.

rains: lying north of that described, and embracing northern and western Scandinavia, Great Britain, Delta of the Rhine, west of France, and southern Europe south of the Carpathians. The district of *summer rains:* extending over eastern France, Netherlands, except the Rhine Delta, north of Switzerland, Germany north of Alps and Carpathians, Denmark and southern Scandinavia, Central Europe, and the country beyond the Urals to the interior of Siberia. In South America we find heavy rains occur on either side of the equator, and except the rainless district on the western coast, south to the tropic of Capricorn; beyond that line mild summer rains on the eastern, and heavy winter rains on the western side of that continent are met with; at Tierra del Fuego there are constant precipitations.

160. Within the tropics—the *calms* excepted—we find the striking peculiarity of wet and dry seasons, depending upon the position of the sun and the direction of the wind. When rain falls near the equator it descends in great abundance during the day, and continues for some weeks. At Arracan, in Burmah, in lat. 20° 30′, in July 1825, nearly 60 inches fell, and in August about 43 inches. Malcom[1] mentions that from 150 to 200 inches fell in the maritime parts of Burmah during the rainy season. At Demerara a fall of 6 inches has been observed in twelve hours; and at Cayenne, in February alone, 160 inches.[2] At Bombay 32 inches have been collected during the first twelve days of the rainy season: this is the average annual fall in England. Rain often descends with great impetuosity in a comparatively confined locality, if mountains are present to alter the humidity and temperature of the atmosphere. "We have just had," says Bennet,[3] "a remarkable instance of the occasionally limited locality of rains in these latitudes,—Huahine. At the settlement there has not been a shower all day; but on the mountain tops immediately adjacent, such floods have fallen that we can count twelve cascades pouring down with great im-

[1] Travels in Burmah.

[2] Humboldt,—Pers. Nar. v. vi. p. 276, *note* on authority of Roussin.

[3] Tyerm. and Ben.—Jour. v. i. p. 527.

petuosity, and in large volumes, over the rocks into the valleys, from heights of not less than 300 or 400 feet."

161. Remarkable exceptions are met with in tropical countries to the general law mentioned. Thus, at Cumana in South America, lat. 10° 25′ N., and long. 64° W., the annual fall does not amount to 8 inches; and on the same coast, there are other places where for years together rain does not fall at all, though, from the humidity of the atmosphere, vegetation does not suffer. Humboldt mentions that in the equinoxial basin of the Atlantic, the humidity, when compared with Geneva, is as 12 to 7, a striking difference. For many hundred miles along the coast of South America, rain is unknown. Thus, from Amotape in S. lat. 5° to Coquimbo in S. lat. 30°, the whole country is a barren desert,[1] excepting where streams descending from the Andes water the ground; a peculiarity dependent upon the presence of these mountains and the direction of the winds. The deserts of Asia and Africa are also extremely arid; and the dryness of the atmosphere of Upper Egypt is proved by the fact, that seeds which have been found in mummy tombs, after the repose of many centuries, have germinated readily.[2] In the Nile Delta rain very seldom falls; nevertheless, in 1761, it unexpectedly rained so abundantly that many mud-houses were carried away. In Upper Egypt it rains even less frequently, but its want is supplied by copious dews.[3] In the Sa'eed in Egypt heavy rains fall once in four or five years. Lane, in the autumn of 1827, witnessed such an occurrence at Thebes. At Cairo four or five smart showers fall annually.[4] In the Physical Atlas already referred to, we find the following compendium of the *rainless districts of our globe.* In Africa,—the great Sahara. In Asia,—the countries of Arabia and part of Persia or Iran, with the province of Meekran in Beloochistan;—a district comprising an area of about 3,000,000 square miles: the de-

[1] Capt. Basil Hall,—Extracts from a Journal, ii. 12.

[2] In the public prints of August 1847 we read of a field of mummy wheat growing most luxuriantly at Castletown near Dundalk. The seed from which this field of wheat was originally derived, was computed to have lain 3000 years in the tomb.

[3] Hasselq.—Trav. 455; Belzoni,—Nar. v. ii. 137; Russel's Egypt, Ed. Cab. Lib.

[4] Englishwoman in Egypt, let. vi.

sert of Shano or Gobi, a plateau rising from 2400 to 5800 feet above the sea; the table-land of Thibet and part of Mongolia;—a district embracing 2,000,000 of square miles. In America,—various localities, as the table-land of Mexico, part of Guatimala and California, together with the western declivity of the Andes of Peru;—extending to 500,000 square miles. In all, an area of five and a half millions of square miles.

162. The quantity of rain in any locality is increased by the vicinity of mountains, *e.g.* among the lakes of England, along the mountain range of Central Europe, and the alpine tract of Norway. The same cause determines, in some localities, to greater night than day rains. Certain seasons are more remarkable than others for rain, a law which applies over the globe generally; in extra-tropical regions the relative quantity is greatest in winter, and greater in autumn than in spring or summer. The following relative proportions have been given,[1]—winter 50.6%; spring 16.3%; summer 2.8%; autumn 30.3%. Over Europe,[2] the summer rains exceed those of spring—exceptions, however, occur a little north of the Mediterranean. Over the European continent rain is found to diminish in quantity as we approach the north-eastern extremity, where for months together the sky is cloudless; this law, it will be observed, extends to our own island, where the rains are most copious on the western side.

163. In those localities where the number of rainy days is greatest, it generally happens that the amount of rain is least; nor can we estimate correctly the humidity of a climate by the quantity of rain which annually falls there. In N. lat. 12°–43°, the mean number of rainy days is 78; in lat. 43°–46°, it equals 103; in lat. 46°–50°, it equals 134; and from lat. 50°–60°, it amounts to 161.[3] It rains yearly during 64 days at Rome, and 120 at Padua. According to Captain Portlock,[4] the average number of dry days (no rain falling) in London, is 220, and in Dublin, 150. The number of days of heavy rain varies from sixteen to thirty in the former city, and from eighteen to thirty-two in the latter.

[1] Physical Atlas.
[2] Gasparin,—Bib. Univ. tom. xxxviii. pp. 54, 264.
[3] Journ. de Physique.
[4] Rep. Geol. of Londonderry.

164. The area over which rain simultaneously falls is sometimes very great. On February 3. 1842, it rained in North America, from north to south, over 1400 miles: the breadth and boundaries of the district were not ascertained. Rain has been observed to fall in very elevated places; thus, among the Himmalehs, Gerard experienced a shower of two hours' duration at an altitude of 15,000 feet.

165. Rain sometimes falls from a cloudless sky, but in such cases it is either wafted on the wind from a distance, or it arises from condensation of moisture without its passing into the intermediate state of clouds. In the higher regions this vapour may become frozen, even without the semblance of a cloud, and descending to a warmer stratum, be again dissolved, dissipated, or precipitated.

Sir James Clark Ross[1] noticed a curious appearance of this phenomenon in the South Atlantic, on the evening of the 20th December 1839: although the sky was free of clouds, it rained for *above an hour*; the dew-point was 72°, and the temperature of the air 74°. At Geneva, on the 9th August 1837, Wartmann noticed this occurrence for about three minutes;[2] the same phenomenon was again seen there, on the 31st of May 1838, about 7 P.M., for six minutes. A similar rain has been observed for *ten minutes* at Constantinople, and this is the longest duration of the phenomenon, in Europe, with which we are acquainted. According to M. Gentil, it is not a rare phenomenon in the Mauritius.[3] Humboldt[4] met with it at Cumana, on the 5th September 1799, at 3 P.M.

166. Many instances of floods have been recorded. We would distinguish between floods which happen periodically, and such as occur irregularly—the former depending upon the melting of snows, and heavy rains in the neighbourhood of the river sources, at determinate seasons; the latter, upon unexpected rains, long continued or very heavy, or upon an unusual increase of temperature, dissolving an extraordinary quantity of snow upon the snow-clad mountains. Of the first

[1] Voyage in Southern and Antarctic Regions.

[2] Comptes Rendus, tom. v. p. 549.

[3] Ib. tom. xi. p. 327.

[4] Brewster's Jour. vol. iv. p. 181.

of these, we might instance the famous flooding of the Nile, and the inundations of the Orinoco, Amazon, La Plata, Arkansas, Red River, Mississippi, and the Ganges. In illustration of the second, if we revert to the times of the "world's gray fathers,"[1] we would mention the celebrated flood of Ogyges, about 1764 years before the Christian era, when Attica was inundated ; that of Deucalion, which covered Thessaly, about the year 1500 B.C. ; another, during the Trojan war, besides two more recorded by Xenophon. Mohammedan writers mention a catastrophe of this kind—the "inundation of Al-Arem"[2]—which happened in the reign of Akran, the twenty-eighth king of Yemen, about the time of Alexander the Great: but to come down the stream of time,—we find that in 1281, the Tiber flooded, vulgar superstition associating the inundation with the death of Pope Nicholas III.

During the middle ages, high floods were not unfrequently chronicled in this country:—thus, in the year 1237, when Westminster Hall was sailed in with boats,—the summer of that year, after the extraordinary rains, was very dry;[3] and in 1242, this building was again flooded.[4] In 1256, inundations occurred in Bedford ;[5] and in 1287, to the great injury of the eastern counties.[6] In 1339, Newcastle-on-Tyne was flooded—"a hundred and twentie temporall men, with diverse priests, and manie women, were drowned and lamentablie perished.[7] In September 1555, the Hall at Westminster was inundated ;[8] and again in February 1579, when fishes were found in it.[9] In 1570, there were many losses by floods ;[10] and in 1579, Bedford and Huntingdonshire suffered severely[11] from a similar cause. The greatest flood of the middle ages, was that which overflowed the Severn[12] in October 1483, about which time "the sweating sickness" appeared,[13]

[1] Vaughan and Campbell.
[2] Koran.
[3] Paris; West; Holinsh. Chron. vol. iii. p. 220.
[4] Stowe's Surv. of Lond. fol. book. vi. p. 48.
[5] Hol. Chron. vol. iii. p. 254.
[6] Ib. p. 284 ; Dunstable,—Chron.
[7] Ib. p. 355.
[8] Holinsh. Chron. vol. iii. p. 1129; Stowe,—Survey of Lond. 1720, i. 32.
[9] Hol. vol. iii. p. 1271.
[10] Ib. pp. 1222–1224.
[11] Ib. p. 1310.
[12] Grafton's Chron. 1189–1558, 4to, p. 133.
[13] Heckers, Epidem. Mid. Ages.

—for a century this was called "the great waters." In 1607, many found a watery grave from excessive rains.[1] In 1480, most of the European rivers burst their boundaries; in 1484, the Leck overflowed its banks;[2] and in 1485, floods were frequent. In 1649, the Seine inundated Paris. During the middle ages, the coast of Holland has been subjected to repeated inundations, but these have arisen chiefly from irruptions of the sea. South America also, has often suffered by the rolling in of ocean-waves during the earthquakes attending volcanic action in the Cordilleras.[3]

167. In July 1706, the rivers of North Wales flooded by extraordinary rains near Denbigh;[4] a similar calamity was experienced in Ireland in October 1706. Floods occurred in July 1707;[5] and in August 1708, near to Knaresborough.[6] Great rains fell in 1701, and in January 1720, in Lower Peru; also in February and March 1728, in the plains of the Cordilleras, where for forty days it was unceasing—epidemics followed. On the 19th September 1752, there was an inundation in Wales, when 10,000 sheep were lost. In 1771, the "Rippon Floods" occurred in Yorkshire; in the same year there was a fearful flood in Virginia, which swept away the Elk Island, upon which there were several hundreds of horses, oxen, and other animals, besides houses.[7] In 1780, a tremendous rain and ocean-wave swept away the whole town of Savannah-la-Mar, on the west coast of Jamaica.[8] In September 1787, the mountain-torrents of Navarre carried off 2000 persons. In 1790, several houses fell during heavy rain at Lambayeque, in the northern part of the rainless desert of Peru. On the 21st of June 1791, Cuba was visited by a similar catastrophe, when 3000 lives were lost, and 11,700 cattle perished.

An inundation in October 1800, destroyed 1400 persons at St Domingo. In the summer of 1813, Hungary, Poland, and Austria, suffered severely from a similar cause: on the 14th of September, 2000 Turkish soldiers perished in the Danube;

[1] Burns. [2] Werlich,—Chronica, Franckfurt, fol. 239.
[3] Lyell's Princip. of Geology, passim. [4] Ph. Tr. No. 308, p. 2342.
[5] Phil. Trans. No. 320, p. 309, [6] Ib. No. 319, p. 251.
[7] Edwards,—Hist. of West Indies; Bailey's Four Years' Resid. in West Ind.
[8] Edwards,—Op. cit. vol. i. p. 235.

Silesia lost 600 of her inhabitants ; Poland numbered 4000 with the lost ; and the French army suffered severely. In December 1821, there were great inundations in Italy and Switzerland.[1] In June 1822, the Ganges overflowed Backergunge in Bengal, and swept away 10,000 individuals, besides cattle and other property. On the 28th of August 1826, it rained heavily among the White Mountains, in New Hampshire, after a drought which extended to two seasons ; the Saco flooded, and swept down enormous rocks and masses of earth, with noble trees and shrubs which had grown upon its steep and lofty sides—the *débris* of a land-slip. That which was comparatively small in its commencement, grew in magnitude, and its moving power became prodigious ; forests were prostrated, and the whole valleys of Saco and Amonoosuck presented fearful desolation. Eleven years after this catastrophe, Professor Hubbard beheld the deep channels which had been excavated, and the heaps of granite boulders that had been carried down.[2]

On the 15th November 1826, the Anio, a tributary of the Tiber, rose above its wonted level after heavy rains, and produced an inundation which has been thus described by Sir Charles Lyell:[3]—"The waters appear to have been impeded by an artificial dike, by which they were separated into two parts, a short distance above Tivoli. They broke through this dike ; and leaving the left trench dry, precipitated themselves, with their whole weight, on the right side. Here they undermined, in the course of a few hours, a high cliff, and widened the river's channel about fifteen paces. On this height stood the church of St Lucia, and about thirty-six houses of the town of Tivoli, which were all carried away, presenting, as they sank into the roaring flood, a terrific scene of destruction to the spectators on the opposite bank. As the foundations were gradually removed, each building, some of them edifices of considerable height, was first traversed with numerous rents, which soon widened into large fissures, until at length the

[1] Bib. Univ. Jan. 1822.

[2] Silliman's Amer. Jour. vol. xv. p. 216, Jan. 1829 ; Ib. vol. xxxiv. p. 115 ; Lyell's Geol.

[3] Princip. of Geol. 6th ed. i. 367.

roofs fell in with a crash, and then the walls sank into the river, and were hurled down the cataract below. The destroying agency of the flood came within two hundred yards of the precipice on which the beautiful temple of Vesta stands; but fortunately this precious relic of antiquity was spared, while the wreck of modern structures was hurled down the abyss." This classic stream has not unfrequently burst its bonds. Pliny the Younger[1] records a flood which swept into its foaming torrent woods, villas, and works of art. It will be remembered, that before the death of Cæsar, which happened in the year 44, the Tiber overflowed its banks,[2]—

> "Vidimus flavum Tiberim, retortis
> Littore Etrusco violenter undis,
> Ire dejectum monumenta regis,
> Templaque Vestæ."
>
> HORACE,—*Carm.* lib. i. Ode 2.

And at the same time, the Po—"Fluviorum Rex Eridanus"[3]—inundated Lombardy. A few years afterwards, in the short reign of Otho, the Tiber was again greatly swollen,—an event which the Romans accounted inauspicious.[4]

In August 1829, the north of Scotland was visited by a terrific storm, which extended simultaneously over nearly 5000 square miles.[5] Rivers, the united length of which amounted to more than 500 miles, were flooded; and a portion of country lying within two lines drawn from Lochrannoch, one to Stonehaven, and the other to Inverness, was inundated. Many bridges were swept away; that across the Dee at Ballater—near the new royal domain of Balmoral Castle—disappeared, though built of granite: numerous hamlets were obliterated. A fragment of sandstone measuring forty cubic feet, was carried down the Nairn, 200 yards; and the Don "forced a mass of four or five hundred tons of stones, many of them two or three hundred pounds' weight, up an inclined

[1] Epist. 17, lib. viii. [2] Appianus, lib. iv., &c.
[3] Virg.—Georg. i. v. 481; Maur. Honor. Servius,—Comment.
[4] Plut.—Otho, Fol. Ed. 1579, p. 1055; Tacitus,—Annal. lib. i. 76; Ib. Hist. i. 86; Livy; Julius Obsequens,—De Prodigiis, &c.
[5] Sir Thomas Dick Lauder,—Morayshire Floods.

plane, rising six feet in eight or ten yards, and left them in a rectangular heap, about three feet deep, on a flat ground."[1] In 1838, the Rhine flooded; and the Neva inundated St Petersburg. On the 2d–3d November 1834, a flood unparalleled since 1740, occurred at Florence—Rome and Corsica also suffered. The autumn of 1846, was noted for floods in France, equal in violence to those of October and November 1840. It had rained for twenty days incessantly, and the Rhone, Durance, and other rivers, rose far above their natural height. The Loire became a mighty torrent, sweeping villages before it—the tocsin was sounded in the Val, and at midnight the cry was to all, "Sauve qui peut!"[2] In 1847, the flood at Goruchpoor, in India, exceeded all others within two and twenty years. In the autumn of 1848, there were inundations in Warwickshire and Northampton. Major Skinner,[3] referring to the great rains in the east, says, that on entering Caifa, he found the town deluged with a flood, the rain which had lasted several days having risen to the waist. Two men appearing, he asked, "whether this was Caifa, and these the houses?" "They are washed down—behold you see, do you not?" was the reply. Mr Elphinstone,[4] also, mentions a remarkable rain which occurred while he was travelling in Persia, between the Indus and the Hydaspes:—"On one occasion, the rear-guard, with some gentlemen of the mission, were cut off from the rest by the swelling of a brook, which had been a foot deep when they began to cross. It came down with surprising violence, carrying away some loaded camels that were crossing at the time, and rising about ten feet within a minute. Such was its force, that it ran in waves like the sea, and rose against the bank in a ridge like the surf on the coast of Coromandel." In 1833, a Hindoo town was discovered to the north of Saharunpore, near Behat, seventeen feet below the level of the country. From the fact, that in the neighbourhood there are several rivers and moun-

[1] Rev. Mr Farquharson,—Quart. Jour. of Sc. N. S. No. 12, p. 331.

[2] Journal des Debats; National; Sémaphore de Marseilles; Times.

[3] Overland Jour. to India; also Jacob de Vitriaco, Gesta Dei, i. p. 1098; Miscel. Curios. iii. 139; Maundrell's Jour. from Aleppo.

[4] Account of Cabul, p. 78.

tain-torrents, and the peculiar nature of the overlying deposit, which was red alluvial clay and river sand, it is supposed that this town had been destroyed by an inundation.[1]

Inundations may arise from other causes than inordinate rains, *e. g.* from the ocean-waves accompanying hurricanes and submarine earthquakes, obliteration of river-courses by land-slips or ice; obstruction presented by ice at the mouths of rivers flowing from a southern to a northern latitude; high winds blowing in an opposite direction to that of running water; the melting of snow upon volcanoes by the flow of lava, or previous to an eruption;—but these belong to Physical Geography rather than to our present subject.

The following instances of inordinate rains in short periods, are very remarkable:—At Montpellier, an inch of rain was collected in a single hour;[2] at Viviers, on the 6th September 1801, in 18 hours, 13 inches 2 lines;[3] at Catskill,[4] to the west of Hudson River, United States, on the 26th July 1819, in 7.5 hours, 18 inches; at Genoa, on the 25th October 1822, in 24 hours, 30 inches; at Naples, on the 22d November 1826, in 37 minutes, 0.9 inch; on the 7th October 1823, at Perth,[5] in 15 hours, 2.1 inches; on the 3d August 1829, at the same city, in half-an-hour, 0.8 inch; at Gibraltar, on the 27th November 1826, in 26 hours, 33 inches; at Geneva, on the 20th May 1827, in 3 hours, 6.4 inches; at Joyeuse[6] in the Ardêche, on the 9th October 1827, in 22 hours, 31.173 inches; at Brussels,[7] on 4th June 1839, in 3 hours, 4.4 inches; in the basin of the Saône at Cuiseaux, in 68 hours, before the floods of 1841, 10.63 inches;[8] and on the 25th–26th November 1845, at Seathwaite, Borrowdale, in 24 hours, 9.62 inches. Roussin mentions a fall of rain at Cayenne, between the 1st–24th February 1820, amounting to 12.58 feet;[9] in ten hours the Admiral measured 10.9 inches.

[1] Lyell,—Prin. Geol. iii. 287; Capt. Cautley,—Jour. of Asiat. Soc. 1834.
[2] Edin. Encyc. xvi. 514; Jour. de Phys. viii. 437, ix. 391.
[3] Flaugergues,—Bib. Univ. viii.; Ann. Philos. xiv. 111.
[4] Silliman's Amer. Jour. vol. iv. p. 124.
[5] Edin. Encyc. xvi. 514; Jour. de Phys. viii. 437, ix. 391.
[6] Ann. de Chimie, xxxvi.
[7] Compt. Rend. tom. viii. p. 980.
[8] Compt. Rend. tom. xii. p. 260.
[9] Silliman's Jour. vol. iv. p. 375.

168. The size of rain-drops has not been sufficiently observed to enable us to form a precise estimate of their magnitude. In thunder-showers, the rain-drop is greater than in ordinary showers, and in the latter it is larger than in the drizzling rain, or in the thick wetting fog. The size has been estimated at from the 0.25 to the 0.04th of an inch in diameter.

169. Two circumstances particularly determine the temperature of rain-drops,—the thickness and elevation of the cloud. Already have we shown that the atmosphere is colder as we ascend, and that the direct solar rays are very powerful. The one tends to chill the aqueous vesicles, the other to raise their temperature, and in the conflict the latter generally prevails. During the condensation of the particles the temperature is farther elevated by the disengagement of latent heat, and their passage through warmer strata of the atmosphere, but as much caloric is lost by evaporation as probably neutralises the other effects.

170. The velocity of rain-drops depends upon their magnitude and the resistance of the atmosphere. When the latter is equal to their weight, the speed with which they fall will be uniform, and this is what is meant by their *terminal* or ultimate velocity, which is found to be in the subduplicate ratio of their diameters. If a drop measuring the 0.04th of an inch in diameter, has a velocity of 11.5 feet, one the 0.25th of an inch, will gain a celerity of 33.5 feet in falling through the atmosphere.[1]

171. *Theory of rain.* It is unnecessary that we should refer to the unavailing speculations of philosophers upon the production of rain, previous to the year 1787, when Dr James Hutton[2] published an ingenious and plausible theory of its formation. It was reserved for Sir John Leslie to illustrate what Hutton satisfied himself with merely enunciating. "Suppose," says Sir John Leslie, "equal bulks of air in a state of saturation, and at the different temperatures of 15° and 45° cent., were intermixed, the compound arising from such union will evidently have the mean temperature

[1] Leslie,—Ency. Brit., Meteorol. [2] Ed. Ph. Trans.

of 30°. But since, at these temperatures, the one portion held 200 parts of humidity, and the other 800, the aggregate must contain 1000 parts, or either half of it, 500; at the mean or resulting temperature, however, this portion could only suspend 400 parts of humidity, and consequently the difference, or 100 parts, amounting to the 200th part of the whole weight of air, must be precipitated from the compound mass."[1] But this commixture simply, of strata of humid air at different temperatures, will in most cases produce a very small effect, though sufficient to account for the production of a shower. The aid of electricity, as Dr Traill[2] observes, must be called in to furnish a satisfactory explanation of all the phenomena. In endeavouring to explain the suspension of clouds, the individual particles were found to be charged with, and surrounded by electricity. It is merely necessary that this should be withdrawn to have a coalescing of the vesicles and their precipitation, or, upon the approximation of clouds charged with electricity in its opposite states, the attraction of the humid spherules, their coalescence, and descent, either to the earth or for the formation of a cloud in a lower stratum of the atmosphere.

172. Seeing that electricity is an attendant upon this meteor, it will be easily understood why the amount of aqueous vesicles floating near the ground, should vary the electric condition of the atmosphere. To Schubler of Tubingen, and Hemmer of Mannheim, we are chiefly indebted for our knowledge of the state in which the electricity of rain exists. According to the former, the ratio of positively electrified rains to those negatively charged, is as 1 to 1.55; but Hemmer found the proportion to be as 1 to 1.08.

173. The ease with which rain-water decomposes or becomes putrid, indicates the presence of foreign ingredients. That the character and amount of these depend upon local circumstances, is demonstrated by the discordant results obtained from analyses of this fluid. While Zimmerman of Giessen, upon his own investigations, considers the oxide of iron to be one of its constituents, Kastner failed to detect it. That anomalous substances have fallen from the atmosphere is so

[1] Ency. Brit. 7th ed. v. xiv. p. 748. [2] Phys. Geography.

well attested that no one can reasonably doubt such occurrences or reject the evidence; and that prodigies of this kind recorded by the ancients should be cast aside as fabulous, is neither wise nor philosophical. We are not required, however, to believe in their opinions, seeing science has in many instances disclosed the true explanation. M. Nees von Esenbeck has collected illustrations of these phenomena, from records which extend to nearly two centuries before the Christian era down to the beginning of the present century. Of the true nature of those preternatural rains which fell in ancient times we are necessarily ignorant, but doubtless the colouring matter was due to the presence either of an organic substance or some mineral ingredient.

174. Of preternatural rains of the compositions of which we are entirely ignorant, Homer, Herodotus, Ovid, and Dion Cassius make mention. In the year 65, during the reign of Nero, a red rain fell, which tinged the rivers of that hue. M. Salvert[1] informs us that in the year 197 of our era, a shower of *quicksilver* fell at Rome, in the Forum of Augustus,[2] and that Dion Cassius[3] saw it immediately after its descent. In the reign of Egfried, in 684, "it rained blood in Britain and Ireland, that butter became ruddy and the moon became red."[4] In 869, red rain fell during three days in the neighbourhood of Brixen.[5] Holinshed[6] records, that during the rule of Rinall, which began fifteen years before the building of Rome, there fell in England "blood by the space of three daies together; after which raine, ensued such an exceeding number and multitude of flies, so noisome and contagious, that much people died by reason thereof." The same chronicler[7] mentions a fall of red rain for two days in the Isle of Wight, in the year 1177. In the year 1219 or 1222, red rain fell at Viterbo;[8] in 1275, in Wales;[9] in 1416, in Bohemia;[10]

[1] Les Sciences Occultes, tom. i.

[2] "Neither Dion nor Glycas call it *quicksilver*, but the former, *drops of dew like silver*, and the latter, *drops like silver*."—Nor. Brit. Rev. May 1848.

[3] Dion Cassius, lxxv. 1259. [4] Saxon Chronicle.

[5] Hadrianus Burlandus.

[6] Hol. Chron. book iii. vol. i. p. 14,—Matth. Westmonaster, alias Flores Historiarum; Fabyan's Chron. [7] Hol. Chron. vol. iii. p. 101.

[8] Bibl. Italiana, vol. xix. [9] Hol. p. 278. [10] Spangenberg Chron.

in 1459, in Bedfordshire;[1] in 1501, in several places; in 1543, in Westphalia;[2] in 1560, at Emdenaud Louvain;[3] and on the 24th December same year, at Lillebonne.[4] In 1591, red rain fell at Orleans;[5] in August 1618, in Styria;[6] on August 12. 1623, at Strasburg;[7] in 1638, at Tournay; in 1640, at Brussels; in January 1643, at Vachingen and Weinsberg; in January 1645, at Bois le Duc; and about the same time at Brussels.[8]

175. Of preternatural rains having organic compounds entering into their composition, several examples are well authenticated;[9] and in the red snows of arctic and alpine regions, to be hereafter described, we have an analogous phenomenon. Rains of this kind have been examined by Serventini and Zimmerman, and found to resemble that product in constituents. In this class we find rains of substances resembling grain,—pollen rains,—rains of *manna,*—and rains coloured with infusoria. We shall briefly notice some instances of these phenomena. Cole[10] mentions a fall of grain near Bristol, which consisted of the seeds of ivy-berries. Kämtz[11] states that, in June 1830, numerous substances resembling corn were found near Greisau, in Silesia, after a storm of rain. Externally they were yellowish-brown, internally white; they tasted like farina, leaving, however, a disagreeable impression; when rapidly dried they had an almond flavour. It was discovered that these corpuscles were tubercles of the *Ranunculus ficaria*, Lin., which is a common plant in that country. These tubercles are attached to the slender radicles of the plant, the stalks and leaves of which, by the middle of June, are quite dried up, leaving nothing but the roots. Heavy rains wash them from their attachments and expose them on the surface of the earth, thus giving rise to the idea of their atmospheric origin!

Yellow or sulphur rains, as they have been termed—pollen rains—are amongst the most frequent examples of this class.

[1] Hol. p. 649. [2] Suni Commentarii. [3] Fromond.
[4] Natalis Comes. [5] Lemaire. [6] De Hammer.
[7] Elias Habrecht. [8] Kronland and Wendelinus.
[9] Mezery,—Histoire de France, ii. 819; and others.
[10] Phil. Trans. [11] Met. Kamtz et Martins.

So early as 1676, these rains were examined and explained by Elsholtz. A shower of this kind fell at Lund in the south of Sweden, which M. Agardh[1] found to contain the pollen of the *Pinus sylvestris* or Scotch fir, borne on the wind from a forest about thirty-five miles distant. A similar rain fell in 1761, at Bourdeaux. Wormius[2] mentions a shower of yellow rain observed on the 16th of May 1646, at Copenhagen ; and in 1677, the Lake of Zurich was covered with rain of the samecol our. A remarkable fall of yellow rain took place in the spring of 1804, during the night, which created fear in the minds of the people, especially as it was phosphorescent ;—it was found to be a pollen-rain. A *red* rain fell in 1810, in Hungary, which contained pollen from an adjoining forest. On the 9th of June 1835, during a thunder-storm at Banff, the rain was yellow—the waters of the pools in the neighbourhood, and the lee-side of the river Devern, were tinged with the same hue ; as in other instances, this arose from pollen.

The following occurrence is interesting in connexion with the present subject, for in it were the elements, so to speak, of a preternatural rain, the only thing wanting being the descent of the water at the time. On the afternoon of the 11th of June 1847, the wooded part of Morayshire appeared to smoke, and for a time fears were entertained that the fir plantations were on fire. A smart breeze suddenly got up from the north, and above the woods there appeared to rise about fifty columns of something resembling smoke, which wreathed about like water-spouts. The atmosphere now calmed and the mystery was solved, for what seemed smoke, was in reality the pollen of the woods.

176. Analogous to these *pollen-rains*, was the fall of *manna* over Van, in Asia Minor, in 1845, which, according to Professor Miguel, consisted of portions of the *Lichen esculentus*, carried by the wind from a neighbouring forest. The year before, a peculiar substance fell abundantly near Mount Ararat. It was observed that sheep consumed it, after which, in April, it was gathered and made into bread. Thenard and Desfontaines consider that it was a lichen belonging to the

[1] Nova Acta, tom. xii. [2] Mus. i. ii. i.

genus *Lecidea.*[1] The Rev. A. H. Wright, M.D., of the American Mission to Oroomiah in Persia, observes,[2] that he met with a substance in great abundance formed on the leaves of certain trees, called *manna* in Syriac, *gezza* in Koordish. This lichen, *Lecanora esculenta*, or exudation, which Aucher-eloi found in Persia nearly four inches thick, is often the cause of a "fall of manna." Thus, in the time of famine in 1829, during a violent gale, the surface of the ground in Oroomiah became covered with it. It was eagerly sought after for food. More recently, and with the same relief to the wants of the people, a shower of this vegetable product descended at Herat, 876 feet above the sea, during its siege. In April 1846, a shower of manna fell on the grounds of M. Tizenhauz, in Jenischehir, in the government of Wilna. The *lecanora* has been found by many travellers, *e. g.* Wellsted, Wright, Eversham, Ledebour, Aucher-eloi, Bilezekdgi, and Léveille.

177. In 1608, a red rain fell for several miles round Aix, in France, attributed by M. de Peiresc[3] to a liquid emitted by butterflies on leaving the chrysalis. Swammerdam tells us that in 1670, at the Hague, the waters of the lakes and ditches looked like blood. On microscopic examination, myriads of small red animals were detected. These were the *Pulices arborescentes* which abound in ditches, concealed in mud, and sheltered by the aquatic plants; they leave their retreat about June, and for a time may be observed to tinge the waters of a reddish hue.[4] In the south of France, about the end of harvest in 1815, a lake suddenly became red, violet, and grass-green, in spots spreading over its surface; in winter the ice presented the same appearance. Klaproth examined chemically the ingredients, and detected an albuminous matter not unlike indigo. The changes of hue from green to red seemed to depend upon the absorption of oxygen. Another

[1] Ann. de Chimie. [2] Silliman's Journal of Sc. and Arts.

[3] Gassendi's Life of Peiresc, p. 110.

[4] The *Daphne pulex* found in stagnant water where the *lemna* (duck-weed) vegetates, often abounds in such multitudes as to tinge the water red. This minute creature is one of the *crustacea*, and belongs to the great division *Entomostraca*, Müller, and the group *Branchiopoda*, Latreille. The author has met with it abundantly in pipe-water in Birkenhead.

instance occurred in 1825, at the lake of Morat, near Neuchâtel, which, according to Decandolle, was owing to the presence of myriads of infusoria—*Oscillatoria rubescens.* The fishermen of the lake say, that this phenomenon happens every spring, and that the fish are reddened when this appearance presents itself.[1] Professor James Forbes,[2] in December 1826, observed a similar colouring of the Lago d'Agnano. Ehrenberg[3] observes that the water of the Red Sea is coloured by a similar cause. Dr Francis Buchanan[4] records a remarkable milky appearance of the sea, in N. lat. 6° 32′ and E. long. 61° 25′, observed by him on the 31st July 1785. Captain Horsburgh noticed a similar appearance in the Pacific Ocean, due to some species of medusæ; and Captain Tuckey,[5] on entering the Gulf of Guinea, witnessed the same phenomenon. The lamented Professor Chetien Smith noticed a blood-red appearance of the sea on the African coast, near the mouth of the Loango; and similar appearances have been observed on the coasts of China and Brazil, arising from an infinite number of minute molluscæ, floating about at certain seasons. Scoresby[6] describes the green streaked waters of the Greenland seas—the fond *habitat* of whales—and states that this arises from a like cause. We mention these facts with the view of connecting similar phenomena at sea and land, and with the object of offering a probable explanation of the origin of many of the preternatural rains which have been recorded. Water, we may observe, has been found coloured with the dye of certain *fuci.*

178. Of preternatural rains having a mineral composition we have satisfactory evidence; of these, some bear a striking resemblance in their chemical ingredients to meteoric stones, to be hereafter described. On the 3d of July 1529, a violent earthquake was felt in Upper Italy, and immediately thereafter a red rain fell at Cremona.[7] Red rain fell on the 5th

[1] Mém. de la Soc. de Phys. et d'Hist. Nat. de Genève, iii.; Edin. Jour. of Sc. v. vi. p. 307.

[2] Ed. Jour. of Sc. vol. x. p. 257.

[3] La Revu Encyclopédique, xxiii. 783.

[4] Edin. Phil. Jour. v. 303.

[5] Nar. of Exped. to the Zaire, p. 49.

[6] Arct. Reg. i. pp. 176-180.

[7] Antonio Campo, Cremona, &c., Milano, 1645, 4to, p. 150.

and 6th of May 1711, at Orsion, in Sweden ;[1] in March 1721, red rain fell abundantly at Stutgard[2]—a meteor appeared at the same time ; in 1744, red rain fell at St Pierre d'Arena, near Genoa ;[3] on the 13th November 1755, red rain fell in Russia, Sweden, Ulm, and on the Lake of Constance ;[4] the the water was acidulous, and cast down a flaky precipitate, which, when dry, was attracted by the magnet. On the 9th October 1763, red rain fell at Cleves, Utrecht, and other places ;[5] and on the 14th November 1765, at Picardy.[6] In 1781, Count Gioeni observed a cretaceous grey rain on Etna.[7] On the 27th–29th August 1792, it rained without interruption ; a shower of a cineritious substance, attended with explosions and a luminous sky, fell at Paz, in Peru,—fevers and cerebral diseases followed.[8] On the 28th–29th October 1814, red rain fell in the valley of Oneglia, near Genoa.[9] On the 2d November 1819, red rain fell at Blankenberge and Dixmude, in Flanders, and on the following night at Scheveningen ;[10] although it rained nearly the whole day at Blankenberge, the red coloured rain fell only for about fifteen minutes in the afternoon—it was analyzed by MM. Meyer and Van Stoop, who discovered in it muriate of cobalt.

Upon the 23d November 1819, a very remarkable black rain fell at Montreal, accompanied by appalling thunder.[11] It was preceded by dark and gloomy weather, experienced over the United States ; at times the aspect of the sky was grand and terrific. "In Montreal the darkness was very great, particularly on a Sunday morning ; the whole atmosphere appeared as if covered with a thick haze of a dingy orange colour, during which rain fell of a thick and dark inky appearance, and apparently impregnated with some black substance resembling soot. At this period many conjectures were afloat, among which, that a volcano had broken out in some distant quarter. The weather after this became plea-

[1] Act. Lit. Sueciæ, 1731. [2] Vischer. [3] Richard.
[4] Nov. Act. Nat. Cur. ii. [5] Mercurio Hist. y Polit. de Madrid, Oct. 1764.
[6] Richard. [7] Gilbert's Annalen, lv.; Ann. Philos. xxviii. 94.
[8] Mercurio Peruano, 1892, vi. [9] Gior. di Fisica.
[10] Gilbert's Annalen, lxiv. 335 ; An. Gén. des Sc. Phys. Bruxelles.
[11] Ed. Phil. Jour. 1820, ii. 381 ; Annal. de Ch. xv.

sant, until the Tuesday following, when, at twelve o'clock, a heavy damp vapour enveloped the whole city, when it became necessary to light candles in all the houses; the stalls of the butchers were also lighted. The appearance was awful, and grand in the extreme. A little before three o'clock, a slight shock of an earthquake was felt, accompanied with a noise resembling the distant discharge of artillery. It was now that the increasing gloom engrossed universal attention. At twenty minutes past three, when the darkness seemed to have reached its greatest depth, the whole city was instantaneously illuminated by the most vivid flash of lightning ever witnessed in Montreal, immediately followed by a peal of thunder, so loud and near as to shake the strongest buildings to their foundation, which was followed by other peals, and accompanied by a heavy shower of rain, of the colour above described. After four P.M. the heavens began to assume a brighter appearance, and fear gradually subsided." Some are disposed to attribute this phenomenon to the conflagration of a forest, but others consider it to have been a meteor similar to those of the years 472, 1637, 1762, and 1814 (in Canada),[1] to be immediately referred to.

On May 3. 1821, at 9 A.M., red rain fell in the environs of Giessen—it was analyzed by Professor Zimmerman, who detected in it chrome, oxide of iron, silica, lime, carbon, magnesia, and some volatile products. Upon the 15th May 1830, at 7 P.M., and at midnight, red rain fell at Sienna and in the neighbourhood; the weather had been calm for two days previously, but the sky was overcast by dense reddish clouds. Professor Guili observes that this rain contained carbonate of iron, manganese, silica, carbonate of lime, alumina, and some vegetable matter.[2] A black-coloured rain fell on the 22d of April 1846, in the north of Worcestershire; it lasted from 11 A.M. till 1 P.M. and turned the Severn, and the waters in the vicinity of Dudley, Stourport, Abberley, and Bewdley, of that colour. It smelled of soot, and probably was impregnated with carbonaceous matter from the coal-fields adjoining.

[1] P. 158; Phil. Mag. vol. xliv.

[2] Ann. de Chimie.

Saline rains have fallen during severe tempests: thus, in 1703, during the awful hurricane;[1] and in September 1821, in North America, saline particles were found upon the trees many miles from shore.[2] Dalton, in conversation with M. Arago, communicated the fact, that in this country salt water had been detected in the rain-gauge, seven leagues from the coast, carried thither, doubtless, by the wind.

It may be observed, before closing this section, that the ancient river Adonis, rising in Mount Lebanon and falling into the sea near Byblus, has its waters coloured red at certain seasons, a fact noticed by modern travellers. This circumstance, which depends upon the presence of red mud carried down by the periodic rains,[3] doubtless led to the celebrity of Byblus as a chief seat of the polluted worship of Venus and Adonis.[4]

> "Thammuz came next behind,
> Whose annual wound in Lebanon allured
> The Syrian damsels to lament his fate,
> In amorous ditties, all a summer's day,
> While smooth Adonis, from its[5] native rock,
> Ran purple to the sea, supposed with blood
> Of Thammuz, yearly wounded."
>
> *Paradise Lost*, i. 446.

179. Of showers of dust and anomalous substances numerous instances are chronicled. Procopius, Marcellinus, and Theophanes mention the fall of black dust in the year 472, in the environs of Constantinople[6]—Vesuvius was then erupting. During a similar event in the year 79, when the city of Pompeii was entombed, volcanic sand was carried into Syria and Egypt. In 652, red dust fell at the same place;[7] in 743, dust fell in different places, and a luminous meteor appeared;[8] in 929, red sand fell at Bagdad.[9] Spangenberg mentions, that on November 6. 1548, a luminous meteor appeared, and a substance fell resembling coagulated blood; and in 1557,

[1] Phil. Trans. No. 289, p. 1535. [2] Silliman's Amer. Jour. iv. 172.
[3] Lucian,—De Dea Syria, 8; Maundrell,—Trav.
[4] *Adonis*, the *Tammuz* of Ezekiel, chap. viii. ver. 14.
[5] Bentley's Ed. 4to. 1732.
[6] Menœa,—Menolog. Græc.; Zonaras,—χρονικὸν; Cedrenus,—Annals.
[7] Theophanes, Cedrenus, Eretz. [8] Theoph. [9] Quatremere.

a mass of similar appearance fell in Pomerania.[1] On the 3d December 1586, red and black dust fell at Verden, in Hanover, accompanied by lightning and thunder,—or a luminous meteor and explosion. On the 6th December 1637, black dust fell in the Gulf of Volo, and in Styria.[2] In May 1652, after a fire-ball, a viscous matter fell in Italy.[3] In 1689, red dust fell at Venice, which communicated a deleterious quality to the pot-herbs there.[4] On the 24th March 1718, after a luminous meteor, a gelatinous matter was found in the Island of Lethy, in India.[5] In 1719, a fall of sand took place in the Atlantic, in N. lat. 45°, attended by a luminous meteor.[6]

On the 21st May 1737, dust fell on the Adriatic, between Monopoli and Lissa—it was attractable by the magnet.[7] On the 20th October 1755, black dust fell in Orkney;[8] in 1781, white dust, not volcanic, fell in Sicily.[9] On the 8th of March 1796, a dark-coloured substance fell, after a fire-ball, in Lusatia,[10]—Chladni, Guyton-Morveau, and Blumenbach, obtained portions of this viscous matter. On the 5th–6th March 1803, red dust fell in Italy.[11] In July 1811, after a luminous meteor, a gelatinous substance fell at Heidelberg.[12] Upon the 13th–14th March 1813, there fell over Tuscany, Calabria, and Friuli, a great quantity of red dust, red snow, and hail[13]—at the same time, stones fell at Cutro. Sig. Sementini observes, that about 2 P.M. on the 14th, the wind, which for two days had been westerly, becalmed, the atmosphere became cloudy, and the darkness increased so that candles were required—the sky assumed the colour of hot iron—at five o'clock, the scene was terrific, thunder resounded through the air, and the lightning was very vivid—now the sea was heard roaring, although six miles distant from the city, and large drops of red-coloured

[1] Zeiler. ii. Ep. 386.
[2] Phil. Trans. i. 377.
[3] Miscell. Acad. Nat. Cur. Ann. 9. 1690.
[4] Valisniere.
[5] Barchewitz.
[6] Mem. de l'Acad. des Sc. 1719, Hist. p. 23.
[7] Zanichelli,—Opusc. di Calogera. xvi.
[8] Phil. Trans. l. 297.
[9] Gioeni,—Phil. Trans. vol. lxxii.
[10] Gilbert's Annalen, lv.; Ann. Philos. xxviii. 94.
[11] Opuscoli Scelti. xxii.
[12] Gilbert's Annalen, lxvi.
[13] Fabroni,—Annal. de Chimie, lxxxiii.; Jour. de Phys. Mar. 1818; New Mon. Mag. i. 542.

rain descended; towards night, the atmosphere resumed its wonted appearance. Professor Sementini collected some of the powder which had fallen, in which he found crystals of pyroxene; upon analysis, he detected the following ingredients:—In 100 parts,—silex 33, alumina 15.5, lime 11.5, chrome 1, iron 14.5, carbonic acid 9; = 84.5, loss 15.5: observing so much loss, he repeated his analysis, and found that he had not been incorrect, but pursuing the investigation, he detected some organic principles present in it.[1] In July 1814, black dust fell in Canada;[2] and towards the end of September 1815, a similar powder fell in the South Sea.[3] On the 13th August 1819, after a fire-ball, there fell an offensive gelatinous mass;[4] and on the 13th of August 1824, dust fell from a black cloud, at the city of Mendoza, in Buenos Ayres,—at the distance of forty leagues, the same cloud again discharged itself.[5] Dust fell at Genoa on the 16th May 1846, which was collected by Pictet and sent to Ehrenberg; it occurred after a storm. On being subjected to microscopic investigation, Ehrenberg[6] found that it was in every respect identical with that collected at Malta in 1834, and with that met with off the Cape de Verd Islands. In colour, the Genoa dust is ferruginous, the iron being supposed to arise from the contained *gallionelles*. Above forty species of microscopic infusoria were detected in it; and this is singularly interesting in its bearing upon a common origin, that the predominating species in the dust from Genoa were identical with those found in specimens examined, which had fallen at other places and times. The following were detected,—A. Polygastrica: *Campylodiscus* clypeus; *Chætoglena* volvocina; *Cocconeis* lineata; *Diploneis* didyma; *Discoplea* atmosph.; *Eunotia* amphioxys, diodon? gibberula, modon, tridentula; *Fragilaria? Gallionella* crenata, distans, granulata, procera; *Navicula; Pinnularia* borealis; *Stauroneis; Surirella* croticula; *Synedra* entomon, ulna;—B. Phy-

[1] Bibl. Brit. Oct. 1813, April 1814; Schweigger's Jour. xiv. 130; Brugnalti's Gior. di Fisica, i.; Ann. Philos. xi. 466.

[2] Phil. Mag. vol. xliv. p. 191.

[3] Phil. Mag. July 1816, p. 73.

[4] Silliman's Jour. ii. 335.

[5] Gaz. de Buenos-Ayres, Nov. 1. 1824.

[6] Berlin Monats-Bericht. 1846, pp. 202–207; Quart. Jour. Geol. Soc. No. x. Silliman's Jour. N.S. No. xii. p. 423.

tholetharia: *Amphidiscus* anceps, clavatus, Martii; *Lithasteriscus* tuberc.; *Lithodontium* hurs., falcatum, fureatum, nasutum, platyodon, rostrat.; *Lythostylidium* amphiodon, clava, fornica, quadrat., rude, serra, spiriferrum. Similar dusts were collected in the years 1830, 1834, 1836, and 1838. Ehrenberg observes, that it is natural to suppose that these are of African origin, but they contain, besides continental infusoria, marine organisms, *e. g.* the *diploneis*, which are met with only in seas, and never in fresh water. These dusts, too, contain species peculiar to South America, and are deficient in those special to Africa.[1]

180. Many dust-showers have a volcanic origin. So recently as the 2d of September 1845, a powder fell in the Orkney Islands from the N.W., covering the fishing-boats at sea, and on the 3d, upon two vessels near the Faroe Isles. It was found to have been thrown from Hecla, then in violent action. The dust was examined by Professor Connell, and found to contain silica 59.2$\frac{0}{0}$, alumina 15.2, oxide of iron 9.6, lime 4.82, magnesia 0.6, soda with potash 6.74, water and other volatile matters 3.03; $=99.17$. The specific gravity was 2.21; it had a pale brown colour, and with a magnet a few particles could be separated.[2] In 1783 a similar event occurred,—Hecla erupted, and dust fell in Orkney.[3] The sun was obscured by the dust which that year issued from the Skaptàr Yökul. It is well known, that during eruptions of Vesuvius[4] and Ætna, volcanic dust has been carried to great distances, and even to have darkened the sky. We have already referred to the volcanic dust which fell in the years 79 and 472, in Italy and Turkey respectively. While Vesuvius was active in 1138, sand was dispersed over Calabria; in 1631, it reached Constantinople; and in 1794, it again spread over the former place. In October 1822, dust which obscured the sun fell at Amalfi, sixteen miles from Vesuvius, which was then erupting. A mountain ridge which lies between, prevented the people from knowing at the time the cause. During the same eruption,

[1] Phar. Times, 1847, ii. 311.

[2] Connell,—Ed. New Phil. Jour. vol. xl. p. 218; Forchhammer,—Pog. Annal. lxvi. 458.

[3] Dr Barry,—Hist. of Orkney.

[4] Valetta, and others.

dust fell so thickly at Torre del Greco, Bosche tre Case, and Resina, that lights were burned at noon, and "the people walked the streets with lanterns, as is often done at Quito when Pichincha is in eruption."[1] On the authority of Humboldt and Lyell,[2] the eruptions of Jorullo in Mexico, which began on the 28th September 1759, caused darkness, by reason of the dust which afterwards descended in Queretaro, more than 160 miles distant; and in 1819, a similar obscuration attended the emission of the dust, which fell to the depth of six inches upon the streets of Quanaxuato, 140 miles from the volcano. On the 4th April 1768, lights were required at Hambato and Tacunga at noon, in consequence of the ashes from Cotopaxi. Sir Stamford Raffles[3] mentions, that during the éruption of Tomboro in Sumbawa, in 1815, dense clouds of dust covered the sky even in Java, distant in a direct line 300 miles from the crater. On April 27. 1812, an impalpable powder fell during the deepest darkness in Barbadoes,[4] and upon the decks of vessels 200 miles from St Vincent, when, after the repose of a century, the Suffriere volcano erupted. According to Faraday, this dust contained silex $78\frac{0}{0}$, alumina 11.2, lime 7, oxide of iron 3.4, loss 0.4; = 100. On the 24th of February 1835, the sun shone with a sombre light upon Jamaica, and the following morning there fell a fine white dust. The cause of the phenomenon was the eruption of a volcano near San Salvador, eastward of Guatamala, on the shores of the Pacific, which occurred on the 22d–23d of January. Thus, the volcanic dust was carried E.N.E. nearly opposite to the direction of the trade wind,—a distance of about a thousand miles. On the 9th of February 1839, an eruption took place at Baklichli, fifteen versts west of Bakou, from one of the mud-volcanoes there,—lumps of earth were cast up, and a great amount of small hollow spheres, like shot, consisting of a black earthy calcined substance, were borne by the wind to the distance of six leagues;[5] the jets of fire were seen forty versts off.[6]

[1] Humboldt,—Ann. of Philos. xxii. 129.
[2] Vetch,—Lyell's Princip. of Geol. i. 379.
[3] Hist. of Java, i.; Brande's Jour. i.
[4] Jordan,—Jour. of Sc. vol. viii.
[5] Research. in Cent. Asia,—Humboldt, Nor. Brit. Rev. v. 489.
[6] Eichwald.

A "shower of earth," said to have "fallen from heaven," overwhelmed the city of Oujein or Ozene, in Central India, about fifty years before the Christian era. Although it is not recorded that a volcano was then in action, doubtless that was the cause of the catastrophe. According to tradition, eighty other towns in Malwah and Baghar were at that time destroyed by a similar cause.[1]

181. In addition to the abnormal rains described, we would refer to the still stranger phenomena of showers of flesh, fish, frogs, grasshoppers, worms, &c.[2] ! From the circumstance of substances resembling flesh covered with skin, having been found upon the earth, it is not surprising that an atmospheric origin should have been assigned to them. We are told by Signor Carlo di Gimbernat,[3] that a substance called zoogène, which bears a striking resemblance to human flesh, both in physical characters and chemical composition, is occasionally met with; that it was found to cover the thermal springs of Baden and Ischia, and was detected on rocks in the valleys of Sinigaglia and Negropont, at the base of Epomeo, below which, according to some mythologists, Typhon was confined. This product is so singular that we shall attempt to describe it. It has received several names, *e. g. theiothermine*,—Montheim,[4] whose account of it is the best; *glairine*,—Anglada; *baregine*,—Longchamps, from the thermal sulphureous springs of Bareges, in the Pyrenees; *animal extractive, or baregine*,—Gairdner.[5] It is found in the mineral springs of Aix-la-Chapelle, Burtscheid, Baden in Austria, Baden in Switzerland, Bagnoles, Ax, Bareges, &c.;[6] and by Gimbernat, in the thermal vapours arising from Vesuvius and the Solfatara of Pozzuoli. It was recognised as a distinct substance by Scheuchzer about the beginning of last century, and in 1747

[1] Asiat. Res. vol. vi. p. 36; Asiat. Jour. vol. ix. p. 35; Sir J. Malcolm's Cent. India, App. No. ii. p. 324; Brit. Ind.—Ed. Cab. Lib., vol. iii. p. 347; Lyell's Princ. of Geol. iii. 282; Rees' Cyclop., where the catastrophe is partly attributed to an inundation.

[2] Ed. Jour. of Sc. vol. ix. p. 154.

[3] Jour. de Pharmacie, 1821; Bib. Univ. Genève, xi. 150; Giornale di Fisica.

[4] Die Heilquellen v. Aachen, Burtscheid, Spaa, Malmedy, u. Heilstein 1829, p. 248.

[5] Min. and Therm. Springs, 1832, p. 43.

[6] Alibert,—Precis des Eaux Mineral, 1826, p. 217.

its true animal nature was shown by Lemonnier. Since then its properties have been investigated by Vauquelin and others. It bears a greater resemblance to mucus than to gelatine or tannin, but it does not exactly agree with any one of these; it is unctuous, greyish-white, and, when cold, inodorous and tasteless; it is soluble in hot water, and then resembles thin beef-tea. It burns with an animal odour, and yields, by destructive distillation, hydrogen and carbonic acid. Caustic alkalies dissolve it, but neither alcohol nor ether; nitric acid disengages nitrogen, as it does from flesh; strong sulphuric, hydro-chloric, and acetic acids feebly precipitate its aqueous solution. Nitrate of silver and acetate of lead throw it down, but not copiously. No reaction occurs with corrosive sublimate; tannin produces turbidity, and, after standing, a deposit. The theory of Berthier,[1] that it is the product of air and light upon the surface of thermal springs; and of Fabroni,[2] that it is derived from fossil bones by lixiviation and percolation, are inadmissible. To the latter, its geological situation is a sufficient objection, for it occurs in springs issuing from rocks of the primary formation, which have no traces of organic remains, not even "the very elements of organic compounds."[3] By passing aqueous vapour over red hot coals in an iron tube, Döbereiner[4] obtained, besides gases, a substance closely resembling zoogène.

182. That fishes should occasionally be found in such situations as have led to the supposition that they have fallen from the atmosphere, is not wonderful when we consider the power of wind to sweep them from their native element and carry them to dry land, or when we study the peculiar phenomena of subterraneous lakes in connection with alpine streams and volcanoes. The earthquake which precedes the volcanic eruption in the chain of the Andes, shakes the entire mountain, and opens up the subterranean vault. Thus it is that the inhabitants of Quito have become familiar with the *pimelodes cyclopum*, and that they sometimes find their fields covered with mud and fishes. On the night of the 19th–20th

[1] Jour. des Mines, vi. 215.
[2] Giornale di Fisica, 1828, x. 213.
[3] Gairdner, op. cit. p. 46.
[4] Gilbert's Annalen, lviii. 210; Bib. Univ. 1807.

June 1698, when the summit of Carguairazo, to the north of Chimborazo, fell, the surrounding country, for an extent of about forty-three English square miles, was strewed with fishes; and seven years before, a fever raged in Ibarra, in consequence of an occurrence of a similar kind from the volcano Imbaburu.[1] One of the most ancient records of fish having fallen from the atmosphere, in this country, is the following:—"About Easter 1666, in the parish of Stanstead, which is a considerable distance from the sea, or any branch of it, and a place where there are no fish-ponds, and rather a scarcity of water, a pasture-field was scattered all over with small fish, in quantity about a bushel, supposed to have been rained down from a cloud, there having been at the time a great tempest of thunder, rain, and wind. The fish were about the size of a man's little finger. Some were like small whitings, others like sprats, and some smaller, like smelts. Several of these fish were sold publicly at Maidstone and Dartford."[2] A shower of herrings is recorded to have taken place near to Loch Leven, in Kinross-shire, about the year 1825; the wind blew from the Frith of Forth at the time, and doubtless the fish had been thereby carried from the sea across Fifeshire to the place where they were found.[3] In 1828, similar fish fell in the county of Ross, three miles distant from the Frith of Dingwall.[4] On the 9th of March 1830, in the isle of Ula, in Argyleshire, after a heavy rain, numbers of small herrings were found scattered over the fields; they were perfectly fresh, and some not quite dead. On the 30th of June 1841, a fish measuring ten inches in length, with others of smaller size, fell at Boston; and during a thunderstorm, on the 8th of July in the same year, fish and ice fell together at Derby. A prodigy of this kind is recorded to have occurred in France, at a town some distance from Paris, during a violent storm. When morning dawned, the streets were found strewed with fish of various sizes. The mystery was soon solved, for a fish-pond in the vicinity had been blown dry, and only the large fish left behind.[5] So, during a

[1] Humboldt,—Ann. Philos. xxii. 130. [2] Hasted,—History of Kent.
[3] Ed. Phil. Jour. 1826. [4] Inverness Courier, April 1828. [5] Rees' Cyclop.

storm on the 28th of December 1845 at Bassenthwaite, fish were blown from the lake to dry land.

183. Fish are said to fall frequently in India. In 1829, a number fell at Moradabad of the species *cyprinus*. One was found at Benares in the funnel of an ombrometer, five feet above the ground. On September 20. 1839, about two P.M., during rain, there fell a quantity of living fish, about three inches long, and all of one kind, at a place twenty miles south of Calcutta. They were found in a straight line, which is worthy of notice. A fall of fish is recorded to have taken place at Allahabad on May 17. 1835; they were very numerous, and belonged to the chalwa species—*Clopea culstrata*. When the storm had passed, they were found dead and dry.

A shower of mussels, some weighing about two ounces, fell during a severe storm, on the 9th of August 1834, in the United States.[1] The following year another shower of molluscous animals,—*Bulimus truncatus*,—took place at Montpellier.[2]

184. That frogs and other living creatures have fallen from the atmosphere, need not be doubted, but that they have descended in such numbers as to deserve the appellation of a shower, is far from being probable. This subject was discussed in 1844 before the Academy of Sciences at Paris, and instances communicated. The personal observation of M. Peltier was one of the most interesting. It was made in early life at Ham, in the Department of Somme, where he resided. A heavy rain had fallen, and the *Place* was instantly covered with toads. "Astonished at this, I stretched out my hand, which was struck by many of these animals as they fell. The yard of the house was full of them also. I saw them fall on the roof of a house, and rebound from thence on the pavement. They all went off by the channels which the rain formed, and were carried out of the town."[3] Holinshed[4] informs us, that frogs fell in Angusshire during the time of Agricola. Frogs were reported to have descended, during the summer of 1846, over the Humber, upon the decks of

[1] Pittsburgh Gazette.
[2] Athen. No. 423, p. 915, Dec. 1835.
[3] Athen. No. 373, Dec. 1834, p. 923.
[4] Chron. vol. ii. p. 59.

vessels in the river and on the coast near Killinghome lights. The ancients speculated upon the cause of this phenomenon without arriving at a very satisfactory explanation. An opinion of Theophrastes has been adopted by Redi, that these little animals, hidden in fissures of the earth and under stones, had crept out on the descent of the shower; but if we are to receive as true the alleged facts, then the theory of the fall of fish will satisfactorily account for the descent of frogs.

185. Between the years 1500–1503, and 1547–1551, epochs memorable for epidemic visitations, spots of various colours, but chiefly red, suddenly appeared over France and Germany. These have been termed "blood-spots," or *signacula*.[1] Dr Merle D'Aubigné[2] thus describes, from the writings of Zwingle,[3] the appearance of the phenomenon on the 26th of July 1531, shortly before the bloody engagement in which that reformer fell:—"A widow chancing to be alone before her house in the village of Castelenschloss, suddenly beheld a frightful spectacle—blood springing from the earth all around her. She rushed in alarm into the cottage...........but, oh horrible! blood is flowing everywhere—from the wainscot and from the stones;—it falls in a stream from a bason on a shelf, and even the child's cradle overflows with it. The woman imagines that the invisible hand of an assassin has been at work, and rushes in distraction out of doors, crying murder! murder! The villagers and the monks of a neighbouring convent assemble at the noise,—they succeed in partly effacing the bloody stains; but a little later in the day, the other inhabitants of the house, sitting down in terror to eat their evening meal under the projecting eaves, suddenly discover blood bubbling up in a pond—blood flowing from the loft—blood covering all the walls of the house. Blood—blood—everywhere blood! The bailiff of Schenckenberg and the pastor of Dalheim arrive—inquire into the matter—and immediately report it to the lords of Berne and to Zwingle." Such is not an overdrawn

[1] *Vide* Nees von Esenbeck's Sup. to Brown's Vermischte-botanische Schriften 1825, i. 571,—Miscel. Botan. Writings; Ehrenberg,—Poggendorff's Annalen, 1830; Hecker,—Epidem. Mid. Ages,—Babington, 8vo. p. 205.

[2] Hist. of Reformation, book xvi. ch. 5, vol. iv. 1846.

[3] Zwingle,—Ep. ii. 627.

picture of the superstitious terror which these preternatural spots inspired. The same phenomenon occurred in the sixth century,[1] and in the years 786[2] and 959, on all of which occasions the plague broke out with great mortality.[3] It is not to be wondered, that the true origin of these spots,—for they are merely mould, arising from a remarkably luxuriant growth of fungi in a humid atmosphere,[4]—should have been overlooked by the vulgar, and supernatural agency assigned; or that the credulous, in their religious zeal, should have detected in them signs of the cross. That these emblems were supposed to have been visible, we have the testimony of Crusius,[5] who cites the names of persons upon whose clothes they were seen; and informs us of a miller's lad who was burned for his irreligious ridicule! So late as 1819, red mould was seen over Padua, and even then the people became agitated with superstitious fear.[6] Sleiden, but without due consideration, attributed the blood-spots in Germany of 1553, to the excrementitious fluid of an immense swarm of butterflies. Merret, and Peiresc, long since, gave a similar explanation of "bloody rain."

186. The waterspout is a phenomenon closely analogous to the whirlwind, and usually treated of when describing that violent wind. Tournefort[7] the botanist, has given a good account of this meteor, and Steuart[8] mentions one witnessed by him in the Mediterranean, on August 27. 1701. The phenomenon is described by Maxwell;[9] and by the Hon. Captain Napier,[10] as seen on Sept. 6. 1814, in N. lat. 30° 47′, and W. long. 62° 40′, at 1.5 P.M., from H. M. S. Erne. "An extraordinary sort of whirlwind was observed to form about

[1] Hecker,—Geschichte der Heilkunde, lib. ii. p. 146.

[2] Spangenberg, Mansfeldische Chron. 1572, fol. 66; Sigeberti Gemblacensis cœnobitæ Chron. ab anno 381–1113, Paris, 1513, 4to, fol. 58; Hecker,—Epidem.

[3] Hecker,—op. cit. [4] Agricola,—De Peste, 1554, lib. i. 45.

[5] Crusius,—book ii. p. 156; Hecker,—op. cit.

[6] Vincenzo Sette, Mem. sull 'arrossiments straordin. de alcune sostanze alimentose, osserv. nella prov. de Padua, 1819. [7] Letters.

[8] Ed. Phil. Jour. vol. v. p. 40; Ph. Tr. 1702, No. 277, p. 1077; see also, ib. No. 270, p. 805; ib. No. 281, p. 1248; ib. No. 363, p. 1097; Dampier's Voy. vol. i. p. 451; Shaw,—Trav.; Ellis,—Polynes. Res. Lond. 1831, vol. ii. p. 306; Michand,—Mem. Trans. Acad. Turin, in Nicholson's Jour. 4to, vol. i. &c.

[9] Ed. Phil. Jour. vol. v. p. 39. [10] Ib. vol. vi. p. 95.

three cables' length from the starboard-bow of the ship. It carried the water up along with it in a cylindrical form, in diameter, to appearance, like that of a water-butt, gradually rising in height, increasing in bulk, advancing in a southerly direction, and when at the distance of a mile from the ship, it continued stationary for several minutes, boiling and foaming at the base, discharging an immense column of water, with a rushing or hissing noise, into the overhanging clouds; turning itself with a quick spiral motion, constantly bending and straightening, according as it was affected by the variable winds which now prevailed alternately from all points of the compass." Its perpendicular height was estimated at one-third of a mile; before it burst, two others formed to the southward. The following is the description of one seen in the Mediterrenean by Mr Taylor, from H. M.'s ship Minotaur:—The morning was dark and gloomy, threatening thunder, though none was heard nor lightning seen. About daybreak, a dark and heavy cloud hung low over the calm sea, and several waterspouts were suddenly observed about half a mile off, below the cloud. The water seemed raised from the surface of the sea like a cone, and was accompanied by a noise like that of boiling water. From this the water seemed to ascend rapidly in a spout and entered the cloud, where it dispersed in a horizontal direction. The diameter of this spout at the base of the cone was about five feet, and at the entrance of the cloud two feet more. One spout appeared to ascend in a spiral form, and reaching the cloud bent at right angles, and after going some distance disappeared. Another was seen to break and ascend, vanishing in a few seconds, leaving a cone which was carried on with a rapid motion, accompanied by a hissing sound for some distance, when it ascended in a spout, being met by the black cloud which appeared to collect and fall down to meet it. They ascended together. Heavy rain fell at intervals. All the spouts disappeared by separating at the bottom, which was left tapering, and ascending to the clouds. The phenomenon lasted about twenty minutes. Tyerman and Bennet[1] describe several witnessed in the Pacific

[1] Jour. of Voy. and Trav. vol. ii. ch. xxviii. p. 22; ib. vol. i. pp. 49, 548, 557.

Ocean. A remarkable circumstance which attended one of them, was a tube extending horizontally between two clouds, like the vertical column seen in other cases. It was "cylindrical, semi-transparent, smooth, and well defined, except towards the extremities, where at its junction with the dense black masses of vapour between which it was suspended, the edges became ragged and fleecy." Its length was estimated at 3-4ths of a mile; the surface of the sea was calm, with a light breeze at the time, though distant thunder had been heard within a short time of the phenomenon. This curious meteor was formed and dispersed in the atmosphere, which "was effected in little more than five minutes from the time when we discovered the first symptoms of it in the sky, which was otherwise lowering with clouds on either side of the two between which this transverse pipe was projected, and into which it soon resolved itself."

187. In June 1781, a waterspout, attended with lightning and continued rain, occurred in the vicinity of the Llyn-Tegid or Bala lake in North Wales. The Bwlch-y-Groes hills poured down their floods to overflow the country, and as far as Corwen, the sound of the torrents was distinguished. In 1814, M. Griswold was within 430 yards of a waterspout in Illinois, which sent forth lightning without the emission of sound. On June 21. 1817, a waterspout, seen at Lyneham, caused a rapid increase of the Avon; the thermometer in the shade was 86° at Bath. At Salisbury, about 2 P.M., the wind was violent from N.E. with sheets of rain and the fall of masses of ice; an hour thereafter the wind veered to S.W. with great torrents of rain.[1] On August 26. 1823, about 3 P.M., a singular waterspout appeared in the Arrondissemens of Dreux and Mantes. Many trees were torn up in its path, and when it burst over the village of Marchepoy, one-half of the houses were destroyed. The lower part of the waterspout was estimated to be 100 toises in diameter. Large hailstones accompanied, and the whirlwind which attended, besides other disasters, carried a cart heavily loaded from the ground and pitched it above a tilekiln that had been beaten down.[2] In

[1] Howard. [2] Bib. Univ. Oct. 1823, p. 133.

September of the same year, another waterspout and whirlwind committed extensive ravages near Genoa.[1] On the 14th of May 1826, a waterspout was seen at Edinburgh.[2] On the 13th of July 1827, two waterspouts fell upon the Glatz Mountains, causing much devastation to Hautenbach and other places; many persons perished. Mercanton[3] mentions one seen by him on Leman Lake, on the 11th of August 1827, about 7 P.M. On the 25th June 1830, about 2 P.M., a waterspout attended by striking electric phenomena was seen near to Treves.[4] On August 4. 1831, a waterspout passed over a farm at Glauflesk near Killarney, destroying several buildings, and causing the death of seventeen individuals. In 1832, Kämtz,[5] while upon the Rigi, under a serene sky and with a calm air, witnessed the meeting of fogs in the vale of Goldau; a gyratory movement was seen, the vapours advanced with great rapidity, the thermometer fell, and water froze in his anemometer. In the evening, he found that a waterspout had been seen on the Lake of Quatre-Cantons. On the 3d December 1832, one was seen by M. Mayor on the Lake of Geneva; the top of the column did not communicate with clouds above,—none were visible near it.[6] A destructive waterspout occurred at 5 A.M. September 12. 1838, at Kingscourt, Cavan. On the 9th of July 1839, about 10 A.M., the Rev. Dr Dickinson observed a similar phenomenon about a quarter of a mile to sea, off Killiney in Ireland. It presented the form of a double syphon, the longer end of which reached towards the sea, and appeared to approach it, till at length it mingled its waters with the deep. The loop lowering, as if sinking and extending through its own weight, burst, and three streams of water poured into the sea, two of the columns being still united at the top; the sea bubbled considerably at the place. A similar meteor devastated Châtenay near Paris, on the 18th June 1839; and on May 30. 1841, one passed over Courthezon, Vaucluse, overturning about twelve yards of a rampart,

[1] Bib. Univ. Oct. 1823, p. 135.
[2] Ed. Jour. of Sc. vol. ix. p. 131.
[3] Ib. 1827, p. 142.
[4] Schweigger's Jahrb. der Chemie; Brewster's Jour. 1831.
[5] Vorlesungen über Meteorologie.
[6] Biblioth. Univ. 1833.

twenty-six feet high and three feet thick, carrying the materials to the opposite side of the Seille.[1] M. Gasparin[2] mentions a waterspout which burst in the neighbourhood of Orange, Provence, on May 30. 1841. A waterspout was seen off the coast of Ayr on the 25th October 1842, after the snow, which in the early part of the day had begun to fall, had nearly ceased; a part of the dark cloud which was sweeping along in a north-west direction approached the surface of the sea, which assumed a boiling appearance as if discharging steam, and rose vertically in several places. Six were seen at sea off Whitehaven, between 5 and 6 P.M. on September 14. 1845; the deep was violently disturbed. On June 17. 1846, a similar phenomenon was seen at Falkirk, about thirty miles west of Edinburgh.[3] "The day had been unusually warm, perhaps the hottest in the season (thermometer in sun 120° F.), and a suffocating sultriness gave the sky a tropical character. Towards 6 P.M. a dark thunder-cloud was borne slowly along from the west, and when its centre was seemingly immediately over the Black Loch, a spout rather suddenly appeared till its extreme end was hid behind the Callander wood. It was perfectly defined, increasing in density and depth of colour towards its lower extremity, and appeared to be columnar; but from the distance we could not remark any spiral motion. After remaining stationary for nearly a minute, it became more transparent, as if it had discharged itself, and gradually was absorbed into the cloud. The wind was from various directions, as in a thunder-storm; and a few drops of rain fell as the spout was drawn into a cloud." This waterspout burst about a mile west from the Avon bridge, on a rising ground where a vast quantity of water fell. The rain-drops which attended the discharge of this meteor did not extend beyond a circle whose radius was a mile. A waterspout and whirlwind passed Rochester on the 6th August 1846, at 2 A.M.; a rotatory motion and vivid lightnings were observed, with a rushing noise. On the 7th of October same year, during a severe

[1] Compt. Rend. tom. ix. 219; Ib. tom. xiii. 223.
[2] Acad. Sc. 6th July; Lit. Gazette, No. 1277.
[3] Stirling Journal, June 19. 1846.

tempest, waterspouts were seen at Naples. On the 25th July 1847, one fell about 1 P.M. at Morecambe Bay, near Milnthorpe. The column was curved to the south, and appeared *horizontal* about midway between the heavy thunder-cloud from which it descended and the sands; it lasted ten minutes, and was accompanied by vivid lightnings. On August 20. 1847, a similar meteor was seen on sailing from Erie, Pennsylvania, to Cleveland, Ohio.[1] Upon the 31st of August 1848, a whirlwind occurred at Dover, and at the same time a waterspout was seen at Deal, on the east coast of Kent;[2] on the same day at noon, a waterspout was seen at Woodbridge, which passed overland to Hollesley and Bawdsey, on the east coast of Suffolk, where there was a great fall of rain and ice; it burst in the river near Ramsholt.[3] Peltier[4] mentions 137 instances of this phenomenon, of which thirty-three occurred in calms, and ten appeared in a cloudless sky.

188. The pillar of the waterspout consists of condensed vapour; it is often deep indigo-blue, and similar in tint to the superincumbent cloud. When the motions of the base and apex are equal and in the same direction, the meteor presents itself perpendicularly, but it inclines under different circumstances. Electrical phenomena attend its presence, as are indicated by the lightning sometimes observed. It is generally after a storm or long-continued sultry weather, that the meteor appears. It occurs at sea, in straits, by rivers, and sometimes upon land. The discharged water is said to be *always fresh*, consequently not obtained directly from the ocean.

189. Franklin assigns to the waterspout an origin similar to that of the whirlwind—the rushing of a fluid from all sides to a common centre, producing a vertical motion of the particles on their line of meeting. Both phenomena are attributed to electric disturbances. It is true that electrical phenomena attend, but it remains to be proved whether they are not secondary effects. We are disposed to think, that while

[1] Silliman's Amer. Jour. N. S. No. 12, p. 362.
[2] Record of 7th Sept. 1848. [3] Ib. Bury Post.
[4] Traité des Trombes, 1840.

the meteor owes its presence to the agency of electricity, the lightning seen to issue from the column, is induced, by the new arrangement of the aqueous particles. The Count Xavier de Maistre succeeded in imitating the leading peculiarities of the waterspout by mechanical rotation of a fluid; and Peltier[1] artificially formed it, in all its parts, by means of electricity. Meikle[2] assigns a different cause; premising that the *ascending* column arises from the meeting of currents as Franklin supposed, he explains the *descending* column by the condensation of aqueous vapour through "the cold due to the rarefaction which is occasioned both by the whirling motion of the air, and by its rapid ascent. The more swift the rotation, the greater obviously will be the rarefaction and cold; and of course the lower down in the axis or stem will the condensation of the moisture extend." In ascribing this meteor, as some have done, to a vacuum formed over the sea and the elevation of the water through atmospheric pressure, it must not be forgotten that, unaided by other means, pressure can raise the water no higher than about 32 feet.

[1] Traité des Trombes, 1840.

[2] Ency. Brit. 7th ed. vol. xii. p. 135; see also Jones' Physiol. Disquis. p. 595; Johnson's Jour. from India to England in 1817, p. 6; Oerstedt,—Schumacher's Annuaire, 1838.

CHAPTER IX.

190. Hail. 191. Sound previous to its fall. 192. During night. 193. Path of the hail-storm. 194. Theory of formation. 195. Conformation, figure. 196. Remarkable hail-storms. 197. Hail within the tropics. 198. Red hail; acid hail. 199. Snow; forms. 200. Colour, lightness. 201. Chemical peculiarities. 202. Electricity of snow. 203. Amount which falls in different countries. 204. The avalanche. 205. Catastrophe in the Val de Bagnes. 206. Kinds of avalanches. 207. Avalanches of Mont Blanc. 208. Dangers; Dr Hamel. 209. Described by Talfourd; Simond. 210. Casualties. 211. Wind of the avalanche. 212. Eboulement. 213. Utility of snow. 214. Red and green snow. 215. Met with in Europe. 216. Snow-mould. 217. Sleet. 218. The glacier. 219. Magnitude. 220. Dangers. 221. Regular motion of the glacier. 222. Unexpected movements. 223. Crevasses. 224. Forbes' observations on their progression. 225. Destruction; formation. 226. Theory of their motion; gravitation theory of Saussure. 227. Dilatation theory of Agassiz and Charpentier. 228. Viscous theory of Forbes; internal structure. 229. Resemblance to a river. 230. Inclination. 231. Colour. 231. Wind of the glacier. 233. Moraines. 234. Glacier tables. 235. Glacier springs. 236. The icebergs; magnitude. 237. Where not met with. 238. Liable to sudden fracture. 230. Mist-cap of the iceberg. 240. Physical properties of ice.

"Ye icy-falls! ye that from the mountain's brow
Adown enormous ravines slope amain—
Torrents, methinks, that heard a mighty voice,
And stopp'd at once amid their maddest plunge!
Motionless torrents! silent cataracts!
Who made you glorious as the gates of heaven
Beneath the keen full moon? Who bade the sun
Clothe you with rainbows? Who with living flowers
Of loveliest blue, spread garlands at your feet?—
God! let the torrents, like a shout of nations,
Answer! and let the ice-plains echo, God!
God! sing, ye meadow streams, with gladsome voice!
Ye pine-groves, with your soft and soul-like sounds!
And they too have a voice, yon piles of snow,
And in their perilous fall shall thunder, God!

COLERIDGE.

190. Hail differs from rain in temperature and from snow in the aggregation of its particles. It depends upon the co-existence of sudden and intense cold in a humid atmosphere.

The nimbus may be seen approaching, with a snow-like band in the horizon, forming a striking contrast of white and dark-grey approaching to black, with an azure sky; a sense of cold accompanies the rustling wind, a peculiar sound perchance is heard, and hailstones descend, dancing on the ground like pith-balls excited by electricity.

191. The fall of hail is often preceded or accompanied by a loud and peculiar noise. It is long since this was observed. Kalm noticed it on the 30th of April 1744 at Moscow; and Tessier, on the 13th of July 1788 in France. It has been compared by Peltier, who has heard it in the Department of La Somme, to the galloping of horsemen, or it resembles the pouring of shot from one vessel to another. It has been explained by the striking of the hailstones against each other, either by the force of their gravity and the wind, or, as Volta's theory of their formation implies, by their alternate attraction and repulsion between the strata of clouds oppositely electrified. May it not arise in part from the rapidity of its descent through the atmosphere, and the resistance presented to its fall?

192. This meteor rarely appears during the night, though Kämtz[1] records several instances. Hail-storms most frequently occur at the hottest period of the day. In this country they are most abundant in winter; the relative proportions being, in—

Winter, *to all the other seasons*, as	45.5 to 54.5
Spring, ...	29.5 to 70.5
Autumn, ...	22.0 to 78.0
Summer, ...	3.0 to 97.0

In Germany and Switzerland the proportions are somewhat different, as Kämtz[2] has shown from the records of the Meteorological Society of the Palatinate, where the seasons and hours of 440 hail-storms are noted. From that table we find that 194 occurred in spring, 122 in summer, 66 in autumn, and 58 in winter. During the same seasons, the numbers were greatest at 2 P.M., viz.—83, 15, 13, and 10; from 10 P.M. to

[1] Lehrbuch der Meteorologie.
[2] Vorlesung über Met.; Ephemerides Soc. Met. Palatinæ, Mannheim.

4 A.M. both inclusive, we find only 18 hail-storms tabulated, of which, 8 occurred in summer, 5 in winter, 3 in autumn and 2 in spring. That hail falls among the lofty Alps, and even, as Balmat found, on the summit of Mont Blanc, is satisfactorily testified.

193. The path of the hail-storm is generally narrow, resembling in some respects that of the tornado. This was well observed in the storm of April 1697, which passed over the north-west of England; and more recently in that of the Orkney Islands of the 24th of July 1818, the length of which from S.W. to N.E. was twenty miles, and breadth about one-and-a-half. This storm advanced at the rate of about a mile in ninety seconds, not enduring more than nine minutes at any one place, though ice fell nine inches deep: the barometer descended 1.15 in. Tessier mentions one, on the 13th July 1788, which was propgaated *directly* from the S.W. of France to Utrecht; it moved in a double column from S.W. to N.E., with an intervening distance of about twelve miles, where and on either side it rained. The breadth of the column to the west, was nearly ten miles, while that to the east, was five; the one extended very nearly 500, and the other 440 miles. The eastern column passed over Artenay near Orleans at 7.5 A.M.; Andouville in La Beauce, at 8; the environs of Paris, at 8.5; Crespy in Valois, about 9.5; Cateau-Cambresis, at 11; and reached Utrecht at 2.5 P.M. The western column appeared at La Rochelle after a tempestuous night, and crossed not far from Loches at 6.5 A.M.; it passed near to Chartres, at 7.5; Rambouillet, at 8; Pontoise, at 8.5; Douai, at 11; Courtrai, at 12.5; and Flessingue about 1.5 P.M. At each of these places its violence continued only a few minutes, but the execution was most disastrous; property valued at 24,962,000 francs was lost.[1]

194. The descent of hail during thunder-storms, and from an atmosphere highly charged with electricity, led Count Volta and others to assign to it an electric origin; according to which hypothesis, the following conditions are required:—a dry atmosphere above the cloud; speedy evaporation under

[1] Mém. de l'Acad. des Sc. tom. xc.; Epsy on Storms, p. xx.

a powerful sun; clouds superimposed; and an electric condition of these clouds. Professor De Perevoschtchikoff,[1] in an inquiry into the cause of the formation of this meteor, observes that the *nuclei* are the congealed drops resulting from the union of innumerable globules of moisture in the clouds, and that they acquire in their passage downwards new coatings of moisture frozen on the surface of the hailstones, thus he accounts for their volume. The proximate cause of the hard nucleus, he refers to the cold produced by rapid evaporation through the potency of the sun's direct rays, having found that the temperature of water evaporated under the influence of the solar beams does not rise unless the process be conducted slowly. Professor Matteucci conceives that hail is instantaneously formed in the atmosphere. He supposes that the first effect of the sudden cold is the formation of snowy particles, and that by the farther and instantaneous condensation of the vapour of the cloud—through the discharge of electricity—an icy crust is formed around the frozen nucleus. In this way he explains the enormous hailstones which have sometimes fallen. In this view of the formation of hail by the congelation of vesicles, Professor Stevelly[2] agrees. He illustrates the theory of their production—through the intense cold following the abstraction of caloric in the sudden expansion of air to fill a partial void, —by reference to a mine at Chemnitz, in Hanover, where the drainage water is raised by an engine in which the air is heavily compressed. When this air is liberated, such is the intensity of the cold produced by its immediate expansion, that the water carried out with it falls in a shower of ice. Professor Olmsted of Yale College, explains the phenomenon of hail-storms by "the congelation of the watery vapour of a body of warm and humid air, by its suddenly mixing with an exceedingly cold wind in the higher regions of the atmosphere;" but this theory must be abandoned, because it is not sufficient to account for the fall of hail in India, as has been shown by Dr A. Turnbull Christie,[3] and it is doubted even by

[1] Tr. Imper. Soc. of Moscow.

[2] Athen. 1834, p. 714.

[3] Jameson's Ed. New Phil. Jour. 1831.

Olmsted himself, for he says "in this region we know not where to look for the freezing current, unless we ascend so high that there no hot air exists holding watery vapours to be frozen by it." Kämtz attributes *hail-storms* to the conflict of opposing winds. The writer had an opportunity of verifying this meteorologist's observation, on the 18th September 1847. For three days before, the equinoxial gales had been unusually severe—the wind blowing from the S.W., breaking off large branches, and, in a few instances, uprooting trees ; the barometer suddenly fell half an inch. On the night of Friday the 17th it rained impetuously, with much lightning, and hail was observed. The wind veered to the N.W., and continued to blow violently from that point of the wind-rose. During the forenoon of the 18th the dense clouds broke up, and disclosed at intervals the sky ; the direct rays of the sun were powerful, though the air felt cold. There could be seen in the highest region of the clouds a few cirri floating in a south-eastern current ; while below, cumuli were borne in double strata from the N.W., the lower stratum moving with the least velocity. The barometer was now rising, and before next day, had reached the point whence it had fallen. During the 18th hail and rain fell in gusts, the different opposing clouds maintaining the course described.

195. On examining the conformation of a hailstone, it will be found to consist of numerous aggregated particles. The core is often hard and the covering soft, but sometimes this arrangement is reversed. Occasionally they are met with in translucent and opaque layers, alternating, as was the case on the 21st of May 1828, in the Department of Gard, in the S.E. of France, where two hailstones fell, respectively five and four ounces in weight. They present various geometrical forms, being sometimes pyramidal, octahedral, stellated, angular, tabular, conical with a serrated base, spherical, elliptical, irregularly polyhedral, or amorphous. While Kämtz considers the pyramid to be the *primitive form* of the hailstone, others, *e. g.* Descartes,[1] Elie de Beaumont, Airy, Delcros,[2] and Nöggerath, believe it to be the sphere, broken on its fall.[3]

[1] Discours sur les Météores.

[2] Bib. Univ. Fev. 1820, p. 154–157.

[3] Compt. Rend. tom. iv. *passim.*

In size, it varies from one-tenth to one-fourth of an inch in diameter, but sometimes it is much larger.

196. The following are examples of remarkable hailstones. In Scripture we are told that hailstones were miraculously showered down upon the Canaanites, during the memorable combat of Joshua with the five kings of the Amorites.[1] Need we remind the reader of the plague of hail with which the Egyptians were afflicted?—when "there was hail, and fire mingled with the hail, very grievous, such as there was none like it in all the land of Egypt since it became a nation,"—when the terror-stricken Pharaoh cried, "it is enough, entreat the Lord that there be no more mighty thunderings and hail."[2] Miraculous as was this destructive and appalling manifestation of Divine power, it is interesting to observe that the laws of nature were not infringed,—it was electrical. Tibullus[3] mentions the fall of ponderous stones, supposed by Silvius to have been large hailstones. Holinshed records that hailstones as large as eggs fell in England in the year 1202, during the reign of John;[4] and that in the 20th year of that of good King Alexander III. of Scotland (1269), there rose "great winds, with storms of such *unmeasurable* hailstones, that manie townes were thrown down" by their violence, and fires spread throughout the kingdom, "burning up steeples with such force of fire that the belles were in diverse places melted:"[5] those of the Abbey of Aberbrothwick were thus destroyed. In 1339, while Edward III. was marching near to Chartres in France, his army was so much injured by a storm of immense hailstones, that he concluded peace.[6] In 1510, when Louis XII. of France made war against the Pope, and carried his army into Italy, during a thunder-storm bluish hailstones fell, weighing about 100 pounds.[7] On June 21. 1545, there fell in Lancashire "hailstones as big as men's fists, which had diverse prints in them, some like gun-holes."[8] On the 7th

[1] Josh. x. 11; compare with Job XXXVIII. 22, 23; Joseph. Antiq. lib. v. c. 1.
[2] Exod. ch. ix. v. 18 to the end.
[3] Tibullus, lib. ii. 5.
[4] Chron. vol. iii. p. 166.
[5] Chron. Scotland, vol. ii. p. 203.
[6] Matth. Paris; Holinshed,—Chron. v. iii. pp. 393, 394.
[7] Count de Mezeray,—Hist. de France.
[8] Hol. Chron. v. iii. p. 968; Stowe,—Chron. fol. p. 589.

June 1573, hailstones 6 inches in circumference fell in Northamptonshire.[1] On April 29. 1697, a storm passed over Cheshire and Lancashire,[2] which had arisen in Wales. Its course was two miles broad and sixty long; hailstones weighing 8 oz. and measuring 9 inches in circumference, were gathered. On the 4th May, in the same year, a shower of hail fell in Hertfordshire after a thunder-storm, the hailstones measuring 14 inches in circumference, and killing several persons.[3] On May 15. 1703, hail fell at La Perche, as large as an egg,—Parent. Large hailstones fell on June 7. 1711 at Rotherham in Yorkshire;[4] and at Toul, on the 13th July 1753, at 6 P.M., of a similar size,—Montignot and Tressan. At Utrecht, in 1736, they fell in size like pigeons' eggs,—Musschenbröck; and in 1768, at Paris, of great magnitude. In 1784, hail fell among the Pyrenees, weighing 23 ounces. On 5th June 1784, about 2 P.M., at Selborne,[5] hail was found measuring 3 inches in circumference; the air was strongly electric, and rain fell in such a torrent as to move stones weighing 2 cwts.; the storm extended two miles in length and one in breadth. On August 19. 1787, at midnight, hail weighing 9 oz. fell by the Lake Como,—Volta. On the 4th May 1797, in Hertfordshire, one was seen measuring 14 inches in circumference. A mass of ice of enormous magnitude fell in 1803 in Hungary. Hail as large as walnuts fell on the 8th February 1801, upon the British fleet in Marmorice Bay, in Asiatic Turkey.[6] Masses of ice, having a perimeter of 3 to 9 inches, fell on the 15th July 1808 in Gloucestershire,—Howard. A hailstone, measuring 6.5 inches in diameter and cuboidal, fell near to Birmingham on the 8th June 1811; it resembled a congeries of masses about the size of pigeons' eggs, agglutinated together. The same year, Muncke weighed hailstones of 4 oz. troy, collected in Hanover. In August 1813, hailstones like eggs fell upon the British army in the pass of Maya in the Pyrenees;

[1] Hol. Chron. v. iii. p. 1258.

[2] Leigh's Nat. Hist. of Lancashire, &c., fol. 1700, book i.—curious plate; Dennis de Coetlogon,—Univ. Hist. of Arts and Sc. fol. 1745, vol. ii. p. 425.

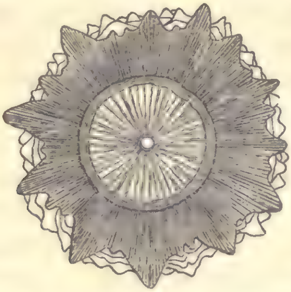
[3] Phil. Trans. vol. ii. 147.

[4] Ed. Phil. Journ. vol. x. 363.

[5] Nat. Hist. of Selb. lxvi.

[6] Sir Rob. Wilson's Hist. Brit. Exped. to Egypt, vol. i. p. 8.

the storm lasted twenty minutes, but was not accompanied by lightning or thunder.[1] On June 4. 1814, hail from 13 to 15 inches diameter fell in Ohio. In the summer of 1815, during a thunder-storm at Malvern in Worcestershire, hailstones fell as large as walnuts, and in some places to the depth of several inches. In the Orkney Islands, on the 24th July 1818, during thunder, a very remarkable shower took place ;[2] on that occasion they were gathered as large as a goose-egg, mixed with large masses of ice. M. Delcross[3] mentions that spherical



Section of Hailstone observed by Delcross. (Edin. Phil. Jour. vol. xi.)

hailstones, measuring 15 inches in circumference, fell at Baçonniere on the 4th of July 1819. Matteucci mentions a hailstorm which overthrew walls, destroyed trees, and wounded cattle ; some of the hailstones weighed one pound and a half, one as much as 14 pounds, and another forced the roof of the house upon which it fell. In May 1821, they were met with of great size at Palestrina in the Roman States. On the 7th of May 1822, hailstones fell at Bonn, 1.5 inches diameter, weighing 300 grains ; men and animals were killed by them. Nöggerath[4] mentions that the masses had a concentric structure around an opaque white nucleus, the layers increasing in translucency as they approached the external surface ; they had a fine stellular fibrous arrangement from rows of radiating air-vesicles. On the 9th of August 1828, pieces of ice,

[1] Ed. Phil. Jour. vol. ix. p. 194.

[2] Neill,—Ed. Roy. Soc. Trans. vol. ix. p. 187. [3] Bib. Univ. Feb. 1820.

[4] Nova Acta Physico-Med. Acad. Cæsar. Leopold. Carolinæ Naturæ Curiosorum, xi. ii.; Ed. Phil. Jour. xi. 326.

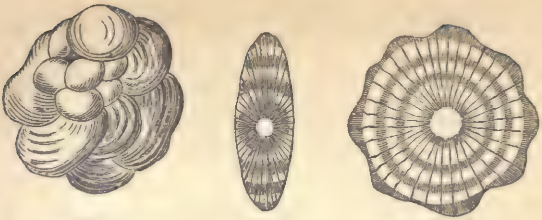


Fig. 1. Fig. 2. Fig. 3.

Fig. 1. External aspect of Hailstone observed by Dr Nögerath, May 7. 1822, at Bonn.
... 2. Section of one in direction of shorter axis.
... 3. Section showing concentric rings and radiations. (Edin. Phil. Jour. vol. xi.)

some of which measured 3 inches long and 1 broad, fell at Horsley, Staffordshire.[1] On June 5. 1829, hailstones and large masses of ice fell at Cazorta in Spain, the largest pieces weighing above four pounds. On October 5. 1831, masses as large as a goose-egg fell at Constantinople. On May 8. 1832, an immense mass of aggregated hailstones fell in Hungary, which measured about a yard in length, and nearly two-thirds of that in depth; the same year, on August 13, very large hail fell on the Nile, weighing from 3 to 16 troy ounces. In June 1835, hail measuring fully 3 inches in circumference, fell from a dense cloud during a thunder-storm, near to Edinburgh: they were bluish, elongated, and when broken presented a conglomerated appearance; they fell about 18 inches apart. On August 1. 1846, during one of the most appalling thunder-storms on record, hail weighing from 1 oz. to 2 oz. avoird. fell in London, destroying a vast amount of property,—Buckingham Palace, Westminster Hall, and numerous other buildings were much injured; the loss sustained by gardeners alone, was estimated at £15,000. During a terrific thunder-storm on the 4th of February 1847, in New South Wales, hailstones of enormous magnitude fell abundantly; they were from the size of an egg to that of an orange, and measured 14 inches round; the forms were very varied.[2] On the 26th of May in the same year, very large hailstones fell at Berlin; and on the 18th July, at Leipsic, killing many of the feathered tribe. In North America, they are frequently very large,—Olmsted. According to Sir John Leslie,[3] the

[1] Ed. Jour. of Sc. v. ix. p. 354.

[2] Even. Mail, July 23–26. 1847; Syd. Morn. Her. [3] On Heat and Moisture.

destructive force of a hailstone is equal to the 4th power of its diameter.

197. Although the south of Europe is the place most frequently visited by devastating hail-storms, the tropics are not altogether free from them. Denham and Clapperton witnessed hail in the interior of Africa ; and on the 17th August 1830, it fell thickly in Mexico. Many instances are recorded of large hailstones having descended in India. For example, Dr A. T. Christie[1] observed very large hailstones fall in May 1823, at Hyderabad, elevated about 1000 feet ; the quantity was so great, that a sufficient supply was obtained for the cooling of the wine of a military mess for several days. The same officer witnessed the fall of hailstones, varying in size from that of a filbert to a pigeon's egg, in the summer of 1825, at Darwar in N. lat. 16° 28′ and E. long. 75° 11′ ; a similar storm occurred in 1826 at the same place, which is elevated above the sea not more than 2400 feet, and near no mountain-range. Lieutenant-Colonel Bowler witnessed hailstones as large as walnuts, at Trichinopoly, in 1805. He observed a similar fall of hail in April 1817, in the Goosam Valley, about twenty-five miles west of Ganjam, situated nearly on the sea level ; the hail fell about 3.5 P. M. after a very sultry day with hot winds and heavy clouds of low altitude. The same officer mentioned to Dr Christie other hail-storms which he had experienced in India, particularly one as Masulipatam, on the coast of Coromandel, in 1822. The most extraordinary hailstone on record, is said by Heyne[2] to have descended near Seringapatam, towards the close of Tippoo Sultan's reign ; it was as large as an elephant ! We presume an *Indian* elephant, grown under the influence of eastern fable ! In India, hailstones fall only during the warmest diurnal period, and after their descent the atmosphere feels exceedingly cold.

198. Red-hail is said to have fallen in Italy in March 1813. Baron Humboldt, though not on his own authority, states that a similar phenomenon was witnessed at Paramo de Guanacos, on the road from Bogota to Popayan, in South America. Hail containing nitric acid fell in June 1842 at Nismes.[3]

[1] Jameson's Jour. 1831. [2] Hist. and Statist. Tr. on India.

[3] Ducros,—Jour. de Pharm. Avr. 1845.

199. Snow is formed by the slow congelation of the moisture floating in the atmosphere. It descends in flakes of exquisite beauty.[1] These frequently fall in the shape of six-pointed stars,[2] formed by the union of prismatic rays at angles of 60°. From each of these rays others of the same form may arise set at a similar angle, presenting a feathery appearance of great regularity and beauty. Scoresby[3] has particularly described the forms and combinations of these snowy crystals, dividing them into five chief, and several minor varieties. These forms may be thus described :—*α. Laminated crystals*, thin, of delicate structure, and of various forms : *a.* stars of six rays, with or without parallel facets rising from the rays ; *b.* regular hexahedrons of various sizes, plain or with lines of distinct geometrical figures marked upon their surface ; *c.* combinations of hexahedrons, broken on the periphery but preserving regular forms,—these very various ; *d.* hexahedrons variously combined, having rays and salient angles,—exquisitely beautiful. *β. Flakes with spherical nucleus*, or a plane with facets ramifying in other planes : *a.* composed of thin crystals like those described, or studded on one side or both, with small needles at a determinate angle ; *b.* having spherical nucleus studded with small needles pointing in all directions—the nucleus crystalised. *γ. Delicate hexangular needles or prisms. δ. Pyramids* with six facets and base. *ε. Prisms*, or slender needles, bearing at one or both ends polyhedral lamina. Upon the 14th of January 1838, nineteen distinct varieties of snow-crystals were seen to fall in this kingdom.[4]

Considerable differences are met with in the appearance and size of the snow-flakes, depending upon the temperature of the atmosphere ;—thus, in a keen frosty air, they are more minute and hard than when they occur in warmer weather. The snow which falls in polar regions is small and powdery, producing a peculiar sensation when received upon the body. Attention has not unfrequently been drawn to the curious appearance of natural snow-balls, arising probably from the drifting of some particles of snow across the snow field, which,

[1] Dr Neh. Grew. [2] Clarke,—Trav. in Russia, vol. i. 11.

[3] Arct. Reg. vol. i. ; Encyc. Metrop. *art* Meteorol. pl. 3.

[4] Roy. Ir. Acad. Feb. 26. 1838.

by gathering others in their course, increase to balls of considerable size. Howard observed, in January 1814, some thousands of them; Sherriff, in February 1830, witnessed them in East Lothian. Professor Cleveland, in 1815, observed them in North America, so late in the year as April; they varied in diameter from 1 inch to 15 inches, were homogeneous, irregularly aggregated, and extremely light. The smaller balls seemed to be formed in the atmosphere, for they occurred in woods and small inclosures; but the larger ones evidently had been rolled by the winds, for their paths were visible.[1]

200. The *whiteness* of snow is consequent upon the minuteness of its particles, a parallel phenomenon occurring in the foam caused by the revolution of the paddle-wheels of a steam vessel; or it may depend upon the reflexion of the minute crystals of which the flakes are composed: a number of mirrors acting in combination, when removed to a distance produce a similar effect. The *lightness* of this meteor depends upon the extent of surface exposed compared with its absolute weight.

201. In snow collected in Berlin, Margraff[2] detected traces of hydrochloric and nitric acids. Link observed the former acid in snow at Breslaw. Gay-Lussac and Humboldt found the air expelled, by ebullition from snow-water, more highly charged with oxygen than that from rain, in the ratio of 34.8 to 32%.[3]

202. Signor Giambattista Beccaria of Turin explains the formation and crystallization of snow, by the action of electricity and the influence of cold. He was led to form this opinion from the observation, that his electrometer never failed to indicate an electric state of the atmosphere when this meteor was falling. Mr Crosse[4] states, that he has collected with his exploring wire, during a driving snow, sufficient electricity for the rapid electrolysis of water, by merely suspending in the glass containing that fluid, two wires of platinum, one connected with the conductor of his apparatus, and the other with the earth. During a snow-storm in America, the tabulating machine of an electric telegraph was

[1] Silliman's Amer. Jour. vol. vi. p. 169.
[2] Chymische Schriften, 1762, i. 273.
[3] Turner's Chem. 8th ed. 1847, v. i. 193.
[4] Sidney,—Electricity, p. 65.

set in motion, though the weather was clear at that extremity of the line.[1] Thunder and lightning are not unfrequently met with during snow-storms in the Andes.[2] Lightning was witnessed in Aberdeenshire about the close of 1846, while snow was falling thickly. Sheet lightning was observed by the writer, on the evening of the 9th February 1847, while snow was lying on the ground to the depth of nearly a foot; shortly after it thundered. At the same place, the author, on the 2d of April in the same year, saw a vivid flash and heard a long peal while it snowed heavily. It is recorded,[3] that during a snow-storm in the winter of 1253, lightning and thunder occurred. *Luminous snow* has been observed; thus, towards the end of March 1813, when a party were crossing Loch Awe, in Argyleshire, returning from Ben Cruachan, suddenly the sky became gloomy, and a shower of snow came on. The lake, which was of a glassy smoothness, with their boat, clothes, the exposed part of the body, and all around, seemed luminous, forming a sheet of fire; this property was not lost by the snow for about fifteen minutes.[4]

203. Where the temperature of winter falls below 32° F, the quantity of snow in any locality, bears a distinct ratio to the amount of evaporation there. In temperate countries the amount is considerably in excess over that in the polar latitudes. The limits of the fall of snow in the northern hemisphere, may be indicated by a curved line, which in the Old World nearly coincides with N. lat. 30°, including all Europe. This line, on traversing the Atlantic, rises to nearly N. lat. 45°, and gradually falls on approaching the American Continent, to the north of Charleston; on crossing the New World it again rises, appearing on the western coast at about N. lat. 47°, and falls to lat. 40° about W. long. 160°. In Europe the number of snowy days increases from south to north:—thus, at Rome it snows in the course of the year 1½ days; at Venice 5½; at Milan 10; at Paris 12; at Copenhagen 30; and at St Petersburgh 170 days. At Nice snow is almost unknown; at Gibraltar and on the coast of Algarve it is not

[1] Henry,—Silliman's Jour. from Proceed. of Amer. Phil. Soc. vol. iv.
[2] Temple,—Trav. in Peru.
[3] Hol.—Chr. vol. iii. p. 249.
[4] Rev. Colin Smith,—Ed. Phil. Jour.; Ann. Philos. xxvi. 154.

met with. Snow fell at Canton to the depth of four inches on the 8th of February 1836,—an unprecedented phenomenon in the memory of the Chinese.[1] Snow does not seem to deepen on the tops of those lofty mountains where the temperature is ever below the freezing-point. This was observed by Dr Martin Barry on Mont Blanc, by comparison of the exposed rocks measured by Saussure and himself.[2]

204. Those great accumulations of snow which are met with in alpine regions, when loosened either by their own weight or the softening influences of winds and the solar rays, give rise to one of the grandest and most awful features of the locality,—

"The Avalanche—the thunderbolt of snow."

The avalanche[3] is the dread of the traveller in those inhospitable regions, where its thunderings break the solemn stillness of the scene, and warn him of danger. Parties proceed in single file, and expedite the journey by avoiding haltings. They advance, guarding against every noise, not even daring to disturb the equilibrium of the delicately poised snow by the vibrations of the mules' bells, which are carefully muffled; thus they wend their way,—

"Mute, lest the air, convuls'd by sound,
Rend from above a frozen mass."
ROGERS.

205. The avalanche on a tremendous scale, is often met with among the impassable mountains of the Caucasus. These immense masses of snow mingled with ice, obstructing in their fall the mountain-torrent in some narrow gorge, wait the bursting of the accumulating waters to sweep destruction before them. Such was the fate of the Val de Bagnes in the Valais. Icy avalanches had fallen from the Mont Pleureur, and obstructed the Drance in that wild and striking gorge. It was in 1595 that the pent-up waters burst their bounds, and swept nearly 150 human beings, besides cattle, onward in the torrent. With a more calamitous result, the mountain stream was again—in the present century—intercepted by

[1] Athen. No. 473, p. 817. [2] Ascent of Mont Blanc, p. 59.

[3] *Synon.—Lavanges, lids, lits; Lavina* of Italy and the Grisons; *Congeres* of the Pyrenees; *Lowen, lauinen* of Germany; *Snee-fond, snee-shred* of Norway.

snowy avalanches and masses of the glacier of Getroz, and a lake formed in the valley between Mont Mauvoisin and Mont Pleureur. The water had accumulated to 800,000,000 cubic feet, of which more than a third part had been carried off by a tunnel, cut by the hardy Vallaisans, under the able direction of M. Venetz the engineer. On the 16th of June 1818, the dike burst, and in one half hour the waters which had accumulated for months were discharged! In less than six hours they had mingled with the Leman Lake, destroying property worth £40,000; forty human beings perished, and more would have been lost had not the people been cautioned to retire.[1]

206. The inhabitants of the Alps distinguish two kinds of avalanches, the *staub-lawinen* and the *grund-lawinen.* The former—or the *drift* or *dust-avalanches*—are not so formidable as the latter, from which there is little hope of extrication. The staub-lawine is formed of fresh fallen loosely aggregated snow, heaped by the wind or drifted into some sheltered spot, where it slips from its resting-place before the sun's rays have melted the surface, and the cold formed it into a mass. Such an avalanche spreads itself over a wide extent. It rushes with enormous velocity, and such is its impetus, that it will ascend the other side of the valley before it stops, overwhelming every thing in its path, prostrating a whole forest if it offers obstruction to its passage. The grûnd-lawine—or *rolling-avalanche*—occurs in spring, when the sun's rays are becoming powerful, and the snow, under its influence, thaws. As that luminary advances, and his beams strike different parts of the mountain, fresh portions of the snow are loosened, and a succession of avalanches constantly falls. Nothing can resist its impetuous descent, and if, through some unusual cause, it leaves its ordinary track, severe calamities are experienced. When the avalanches descend with a slow sliding motion, the Swiss denominate them *suoggi-lauinen* (pronounced suggy) or *rutsch-lauinen*—the creeping avalanches. These often change their original character as they meet with obstructions in their descent. Thus, the

[1] Vide M. Escher de Linth.,—Bib. Univ. tom. viii. 291; Ib. tom. xxii. 58; Brockedon,—Excurs. in the Alps, &c.

creeping-avalanche may become a rolling-avalanche, and, finally, a dust-avalanche, as the inclination of the mountain changes, and projecting rocks catch the falling snow. There is still another, called the ice-avalanche, composed of small fragments of the glacier.

207. The avalanches of Mont Blanc, Monte Rosa, and the Jungfraw, are constantly heard thundering during summer. They are caused by the rays of the mid-day sun, and by certain winds loosening the snow upon the mountain side, or rupturing the glacier reposing at its foot, precipitating them downwards till they find another resting place, or are scattered by the wind. The following is descriptive of such an avalanche. It occurred in July 1845, when Mr Speer and his guide were descending from the Wetterhorn, in the Bernese Alps, whose summit they had safely reached a few hours before. "Our successful triumph over this alarming obstacle having greatly inspired us, we prepared to cross a narrow slope of ice, on which our leader was diligently hacking a few steps. A sudden rumbling sound, however, arrested our attention ; the rear guides drew the rest back with the ropes with violence, and the next moment an avalanche thundered down over the slope we had been preparing to cross, leaving the whole party petrified with horror at the narrowness of the escape. The clouds of fine snow in which we had been enveloped having subsided, we again descended, during three hours, a succession of steep walls of ice and snow, reaching the glacier of Rosenalui at 5 P.M."

208. The character and dangers of these avalanches are well exhibited in the following intensely interesting account of the melancholy attempt of Dr Hamel, a Moscovite, and his party, to reach the summit of Mont Blanc, in August 1820. He was accompanied by Gilbert Henderson, Esq., of Liverpool, Joseph Dornford, Esq., and eight guides. M. Selligue and two other guides did not ascend farther than the Grand Mulet, the resting place of the party during the night. There they had just finished preparations for repose when a thunder-storm came on, and it continued stormy till morning, when the atmosphere became so clear that the Lake of Geneva was visible. The weather, however, was unsettled,

and they resolved to bivouac in the same place for another night; two guides were sent to Le Prieuré for provisions, and Dr Hamel reboiled the mercury in a barometer. At 5 P.M. there was a fall of hail, and until midnight the sky was cloudy; next morning the air was serene and calm, and the party proceeded on their ascent. They reached the Grand Plateau, and were climbing up the side of the mountain, when an avalanche swept away the party, and three of the guides perished. It is thus narrated by Dr Clarke:—"Suddenly I heard," says one of the guides,[1] "a sort of rushing sound, not very loud; but I had no time to think about it, for, as I heard the sound, at the same instant the avalanche was upon us. I felt my feet slide from beneath me, and saw the three first men fallen upon the snow, with their feet foremost. In falling I cried out loudly, 'Nous sommes tous perdu!' I tried to support myself by planting the ice-pole below me, but in vain. The weight of snow forced me over the bâton, and it slipped out of my hand. I rolled down the slope; and when we were all on the very edge of the chasm, I saw the legs of one of my comrades just as he pitched down into the *crevasse*. I think it must have been poor Auguste, for it looked black, and I remember that Auguste had on black gaiters. This was the last I saw of my three companions, who fell headlong into the gulf, and were never seen or heard of again. At this moment I was just falling into the same crevasse, and can but confusedly understand why I did not; but I think I owe my life to a very singular circumstance. Dr Hamel had given me a barometer to carry; this was fastened round my waste by a strong girdle. I fancy that at the moment, this long barometer got beneath and across me, for the girdle suddenly broke, I made a sort of bound as I fell more than 50 feet down, alighting on the soft cushion of snow, and a good deal covered with it above. I suppose before tumbling into the chasm we slid down from 150 to 200 feet, but I cannot tell, for it seemed to me not more than a minute from the time I heard the noise of the avalanche above me, till I found myself lying deep down in a narrow crack; all estimate of dis-

[1] Julien Devouassau, the guide who escaped poisoning by sulphuric acid early in the ascent.

tances, in such situations, must be mere guesses. Couttet's reply to the same question was this: 'I should fancy I slid down nearly 400 feet, and tumbled headlong about 60 feet.' I asked Julien what his thoughts were during this awkward tumble. His reply was in these words,—'Pendant que j'ai roulé, j'ai dit à moi-même, Je suis perdu, adieu ma femme, et mes enfans ! et j'ai demandé pardon à Dieu. Je n'ai rien pensé absolument des autres.' On coming to myself I was better off than I expected. I was lying on my back, heels upwards, with my head resting against the icy walls of the crevasse, and I could see some light, and a little of the blue sky through two openings over my head. I was greatly afraid that some of my limbs had been broken, but I had sunk into the mass of soft snow, and, though bruised by falling against the sides of the ice, yet nothing was broken, and in a few minutes I contrived to get up on my feet. On looking up, I saw a little above me a man's head projecting from the snow. It was Marie Couttet, our *guide en chef.* He was quite covered with snow up to the neck, his arms pinioned down, and his face quite blue, as if he was nearly suffocated. He called to me in a low voice to come and help him. I found a pole in the crevasse ; I went to Couttet, dug round him with the baton, and in a few minutes got him clear of the snow, and we sat down together. We remained in silence, looking at each other for a minute or two, thinking that all the rest were killed. Then I began to crawl up on the snow that partly filled the crack ; and in climbing up I saw above me David Couttet, who was crying and saying, 'Mon pauvre frère est perdu !' I said, 'Non ! Il est ici en bas.' Et moi j'ai dit, 'Les autres sont ils tous là en haut ?' Ils ont dit qu' il manquoit encore trois. Et j'ai demandé, 'Qui sont-ils qui manquent ?' Ils ont dit, 'Pierre Cairriez, Pierre Balmat, et Auguste Tairraz.' Nous avons demandé, si les messieurs avoient du mal ? Ils on dit 'que non.' Then the guides helped us to get about 14 feet on the solid ice. They threw us down a little axe to cut steps, and put down the end of their poles and we got out. We all went to search for the three others ; we sounded with our poles, we cried aloud, we called them by their names, put down a long pole into the snow and listened , but all in vain,

we heard not the slightest sound. We spent two hours in this melancholy search, and by this time were well nigh frozen, for the wind was bitterly cold, our poles covered with ice, our shoes frozen as hard as horn. We were compelled to descend ; we hurried down in perfect silence, and returned to the inn late at night."[1]

209. The gliding of the avalanche has been eloquently described by Talfourd.[2] "You hear the thunder of the unseen avalanches among the recesses of the mountains, and the conviction that you are close to the unmelting miracle which defies the scorching heat that becomes yet more intense ;—but it shall be disturbed—how ? By the sight of that which unseen was so terrible ! From some jutting knob of the size of a cricket-ball a handful of snow is puffed into the air, and lower down, on the neighbouring slant, you observe veins of white substance, creaming down the crevices—like the tinsel streams in the distance of a pretty scene in an Eastern melodrama quickened by a touch of magic wand,—and then a little cloud of snow, as from pelting fairies, rises from the frost-work basin,—and then a sound as if a thunder-clap,—all is still and silent,—and this is an avalanche ! If you can believe this,—can realize the truths that snow and ice have just now been dislodged in power to crush a human village,—you may believe in the distance at which you stand from the scene, and that your eye is master of icy precipices embracing miles perpendicular ascent ; but it is a difficult lesson ; the disproportion between the awful sound and the pretty sight renders it harder. We saw two avalanches during the hour and a half which we spent in front of the cottage,—and learned two other illustrations of the truth that amidst the grandeurs of the universe 'seeing is *not* always believing.'" Somewhat similar to this, is the description of Simond:[3]—"We sometimes saw a blue line suddenly drawn across a field of pure white ; then another above another, all parallel, and attended each time with a loud crash like cannon, producing together the effect of long-protracted peals of thunder. At other times,

[1] See Dr Martin Barry's Ascent of Mont Blanc ; Ann. of Philos. xvii. 33.
[2] Vacation Rambles.
[3] Jour. of Tour and Resid. in Swit. 2 vols. 8vo, 1822.

some portion of the vast field of snow, or rather snowy-ice, gliding gently away, exposed to view a new surface of purer white than the first ; and the cast-off drapery gathering in long folds, either fell at once down the precipice, or disappeared behind some intervening ridge, which the sameness of the colour rendered invisible, and was again seen soon after in another direction, shooting out of some narrow channel, a cataract of white dust, which observed through a telescope, was however found to be composed of broken fragments of ice or compact snow, many of them sufficient to overwhelm a village."

210. A melancholy list of casualties could easily be enumerated ; let the following suffice :—In the year 1478, sixty soldiers were enveloped in an avalanche on the St Gothard ; in 1500, no fewer than 100 perished on the Great St Bernard ; in 1624, an avalanche from the Cassandra on the Italian side of the Alps, proved fatal to 300 soldiers. In 1636, thirty-six persons perished in the village of Randa by an avalanche from the Weisshorn. In 1719, 7000 Swedes perished during a snow-storm among the mountains of Sweden, while marching to attack Drontheim. In 1720, eighty-four men were lost in an avalanche, in the Ober-Gestelen, Vallais, near the Grimsel pass ; on that occasion 400 cattle were killed, besides 120 horses. In 1749, an avalanche bounded from the Crispalt on the south of the valley and fell over the village of Ruaras in the Tavetsch-thal, Grisons ; 100 persons were enveloped, of whom forty perished,—and this is very remarkable, several houses were pushed to a distance so gently as not to awake those who were sleeping in them !—before the cause of the calamity was known, the simple Swiss wondered when it would be day-break ! In 1800, a snow-storm of three days' duration was followed by an avalanche from a precipice in the valley of the Voder Rhein ; it darted across the valley, recoiled from the other side, descended and again recoiled till it reached Trons, burying many of the houses in the snow. At the close of the same year avalanches fell upon the French army while making the passage of the horrifying gorge, the Cardinell, sweeping men and horse into the defile. In 1806, an avalanche fell upon the Val Calanca in the Grisons, carry-

ing before it a number of trees, and *stranding* one on the roof of the parsonage. On December 13. 1808, one fell from the Ruenatsch, upon the village of Selva in the Tavetsch-thal, near the Oberalp, killing forty-two human beings and 237 cattle. In 1814, one from the St Gothard enveloped forty horses laden with goods. In 1820, sixty-four lives perished by this cause at Fettan in the high valley of Engadin in Grisons , in the same year, twenty-three persons were killed at Breig ; and eighty-four individuals, with 400 cattle, perished at the Obergestelen. On December 17. 1825, three guides and a traveller were thus lost on the Great St Bernard. In 1835, an avalanche overwhelmed a party of five peasants and eight horses in the wild glen of Lira, near Pianazzo in the Splügen-pass. On March 22. 1838, an avalanche fell upon the Hospice of the Grimsel, breaking the roof and filling the house with snow ; the servant and dog effected their escape and reached Meyringen in safety,—the avalanche was preceded by an alarming noise heard the night before and on the morning of its fall. In 1827, Biel in the valley of Conches, Upper Valais, was almost destroyed by an enormous avalanche, which began its descent at the distance of nearly two leagues. In 1843, one fell in the Department of Isere, destroying Valsenestre, covering twenty-six houses, and killing ten individuals. One fell from the Aiguilles-rouges on the 15th February 1847, at 7 P.M., burying the hamlet of Chable, situated in the valley through which flows the Arve ; eleven persons escaped, on the third day six were dug out and seven found dead.

211. The *wind of the avalanche,* or current of air which accompanies its impetuous descent, is often productive of loss of life and property. In the winter of 1769–70, an avalanche fell into the Valley of Sixt, *en route* from Geneva to Chamouni, the wind-gust of which uprooted numerous trees growing upon the declivity, and overturned others, together with sheds upon the opposite side of the Gipre river. On December 27. 1819, the village of Randa in the Visp-thal suffered severely from a similar cause, arising from the descent of an ice-avalanche which overhung a precipice of the Weiss-

horn 1500 feet high.[1] One of the spires of the Convent of Dissentis is said to have been thrown down "by the gust of an avalanche which fell more than a quarter of a mile off."[2]

212 Alpine regions are subject, besides the avalanche, to other great calamities. The expansion of the frozen water in the crevices of the rocks often hurls down immense masses of the mountain upon the devoted inhabitants below. This is the *Eboulement*, the *steen-skreed* of the Scandinavians.

> "Mountains have fallen,
> Leaving a gap in the clouds, and with the shock
> Rocking their Alpine brethren; filling up
> The ripe green valleys with destruction's splinters;
> Damming the rivers with a sudden dash,
> Which crush'd the waters into mist, and made
> Their fountains find another channel."
>
> *Manfred*, act i. sc. ii.

In 1248, the town of St André and five parishes were buried by the fall of part of Mont Grenier, facing Chamberry; the ruins, now covered with vineyards, extend over nine square miles, called *Les Abymes de Myans*.[3] On the 4th September 1618, the Monte Conto fell into the Val Bregaglia, in the Grisons, destroying Pleurs and its 2430 inhabitants; all traces of the catastrophe are now nearly gone, only some chestnuts mark the spot. In 1751, part of a mountain fell near Servoz, on the road to Chamouni; and in 1772, three villages were destroyed by part of a mountain which fell in Treviso, in the state of Venice.[4] No less sad were the falls of the Diablerets, between the Valais and the Pays de Vaud, in 1714 and 1749. On the former occasion a strange preservation is recorded. A shepherd of Avers was in his châlet communing in secret with his God, when an enormous mass of limestone was hurled in the direction of his hut. It rested against the rocky precipice and bent over the humble dwelling,—thus was the pious inmate preserved from an instantaneous death! Débris followed and entombed the Swiss, protected from the first danger of the éboulement. All was darkness, and soon a solemn still-

[1] M. Venetz,—Bib. Univ. Fev. 1820, p. 150; Ed. Phil. Jour. vol. iii. p. 274

[2] Murray's Handb. for Switz.

[3] Vide Bakewell's Introd. to Geol.; Trav. in the Tarentaise, i. 201.

[4] Malte-Brun,—Geog. i. 435.

ness reigned, but, says he "I was no longer in fear; I did not lose my courage, and directly I set myself to work to open an issue. A few pieces of cheese which I had made, were my food, and a rill of water which descended among the ruins quenched my thirst. After many days, which I was unable to count in the long darkness of my subterraneous prison, I discovered, by creeping about the rocks, an opening. I saw again the sun's light, but my eyes were for some time unable to bear it. The Almighty, in whom I always confided, and who always kept alive my hope of preserving life, has sent me back to my family, to be a witness and a proof of His power and bounty." When on Christmas-eve, three months after the event, pale, emaciated, almost naked, and spectre-like, he returned to his children, who had been declared orphans by law, the doors were closed against him,—the people were afraid. At last, convincing them of his human nature and identity, he was admitted, and narrated his extraordinary deliverance. On the 2d of September 1806, the Rossberg was precipitated into the Vale of Goldau at the foot of the Rigi,—eight or nine hundred persons perished.[1] On the 4th April 1818, a large portion of a mountain near Sonceboz in the Valley of St Imier, in Switzerland, separated and fell.[2] The Andes are free from both the avalanche and éboulement, but there, the volcano and the earthquake more than supply their place.

213. A snowy covering is of much utility to the ground, by protecting it against the influence of intensely cold winds, and preventing the loss of heat by radiation, partly because this meteor is a slow conductor of caloric, and chiefly by its low radiating force. This is strikingly exhibited in Siberia, where the difference of temperature between the ground under its snowy mantle and the air above, has amounted to 38° F.[3] We observe, too, with what care the Author of nature clothes the animal creation and the feathered tribe in the polar regions, with a covering of corresponding colour, and changes

[1] Nicholson's Jour. xv. 150; Dr Zay,—Murray's Handb. for Switz. p. 43.

[2] Brande's Jour. v. 377.

[3] Sir Ch. Bell,—Paley's Nat. Theol. vol. ii. p. 10.

the fur of the graceful ermine from its summer brown to its winter white. The power of snow to preserve the temperature of the body, so as, under certain circumstances, to allow the vital functions to be performed, though languidly, might be illustrated by instances where the human body and the animal creation, rendered torpid by cold, have been preserved under snow wreaths, and after many days recovered animation. The interesting case of Eliz. Woodcock, who was enveloped in the snow near Cambridge from the 2d to the 10th of February 1799, will be remembered.

214. *Coloured snow.* This phenomenon, although noticed by Pliny,[1] has only in very recent times been made the subject of careful study. It occurs under two very different circumstances,—either while the snow is falling, or some time after its descent. Red snow fell in Armenia in 1056, but its nature is unknown. In March 1678, red snow fell near Genoa, mentioned by Signor Sarotti.[2] Another fall of snow, similar in colour to the last, occurred in March 1803, at Tolmezzo, in the Friaul.[3] In March 1808, rose-coloured snow fell in the Tyrol and Carinthia; and over Carnia, Cadore, Belluno, and Feltri, to the depth of nearly six feet. Its colour was owing to the presence of iron, silex, and alumina. A similar shower fell at the same time in Carniola, and Pezzo, at the extremity of the Valle Camonica; it was preceded by a violent wind on the 5th. White snow had previously fallen, and succeeded this rose-coloured meteor.[4] On the 14th–15th March 1813, red snow fell in Calabria Abruzzo, in Tuscany, at Bologna, and upon the Apennines.[5] On the 15th of April 1816, red snow fell on the mountain of Toual, in Italy;[6] this snow contained an earthy powder, of which the following were the ingredients:—Silex 8 grains, iron 5, alumina 3, lime 1, carbon 2, sulphur 0.25, carbonic acid 0.05, empyreumatic oil 2, water 2, loss 2.25, = 26 grains. These instances sufficiently prove the fact of snow tinged with mineral ingredients falling

[1] "Ipsa nix vetustate rubescit." lib. xi. cap. 35. [2] Phil. Trans. 1678.
[3] Opuscoli Scelti, tom. xxii.
[4] Agardh,—Nova Acta Acad. Nat. Cur. tom. xii.
[5] Bib. Brit. Oct. 1813; and April 1814. [6] Gior. di Fisica, tom. i. p. 473, 1818.

upon the earth ; the other phenomenon is equally established. Sir John Ross collected red snow in N. lat. 75° 54′, and W. long. 67°, which was submitted to the examination of the accomplished botanists, Robert Brown, Francis Bauer,[1] Agardh,[2] and Decandolle. The colouring matter was ascribed to the presence of a vegetable product belonging to the family of Algæ—the *Protococcus nivalis* of Agardh ; *Uredo nivalis* of Bauer ; the *Hœmatococcus nivalis,* or *Palmella nivalis* of others. Bauer observes that the diameter of a full-sized globule of this colouring matter is the 1600th part of an inch, hence 2,560,000 are required to cover a square inch.

The arctic hills upon which Ross observed the red-coloured snow, rise about 800 feet above the sea, and extend eight miles in length. In 1827, Sir W. E. Parry found in the same regions a similar product. He had previously observed that the impressions of the loaded sledges were of that colour, but now he noticed that the footsteps of the party even, produced the same effect ; a similar result followed heavy pressure on almost all the ice they crossed: occasionally the colour was of a salmon hue. Scoresby[3] observes that red snow, collected on Rathbone Island, such as that found by Ross on the "crimson cliffs," in Baffin's Bay, left, on being dissolved, a deep red matter of a granular appearance. Though *red* snow is that most frequently found, *green* snow has likewise been observed, the cause in both cases being similar. Martins[4] and Bravais obtained it of this hue in Spitzbergen. The surface of the snow was natural, but the impressions of their footsteps displayed the coloured appearance, and a little way beneath it looked as if watered with a green decoction. When this snow was melted, the water was slightly tinged. At another time the green colouring matter was dusted, so to speak, upon snow where a large quantity of the *Hœmatococcus nivalis* was met with. Melting this coloured snow, allowing the green matter to subside, then decanting the clear water and submitting the deposit to the microscope, Martins, Du-

[1] Quart. Jour. No. 14, p. 222 ; Roy. Soc. May 11. 1820.
[2] Nova Acta Acad. Nat. Cur. tom. xii. ; Ed. Jour. of Sc. vol. iv. p. 167.
[3] Memor. of Sea, p. 98. [4] Kämtz et Martins,—Meteorol.

jardin, and Biot, found it amorphous, with numerous spherical masses of green *protococcus;* some grains of red and rosy-red colours were likewise seen. The size of the granules varied, and though generally single, some compound granules were detected. The identity of the red snow *(Hœmatococcus nivalis)*, and the green snow *(Protococcus viridis)*, was incontestibly proved.

215. A similar product has been met with in Scotland, on limestone rocks in the Isle of Lismore, in Argyleshire; also upon the Alps and Pyrenees;[1] in Sweden;[2] in Norway;[3] and in New South Shetland. Saussure[4] found red snow on the Breven, and it has been abundantly seen on the Col de Bonhomme.[5] In 1819, the Prior of the Convent of the Great St Bernard, sent to M. Peschier two small bottles containing a portion of red snow melted, with the information that the colour deepened as the season advanced. In the physico-chemical inquiry instituted upon these specimens, M. Peschier[6] concluded that the red colour was derived from two sources—iron in a high state of oxidation, and a resinous vegetable principle—probably united in the same organic product present in the snow. In 1818, it was abundant on the Apennines and Italian Alps. In all these cases, the colour seemed due to a cryptogamic plant, which was observed by the microscope, after evaporating some of the snow upon a sheet of white paper. The green snow has been found in Europe likewise. Baron Wrangle met with it in the province Nerike, and designated it *Lepraria kermesina.* It has been supposed by some, that these phenomena are altogether due to the presence of myriads of minute animalculæ; more recently this view has been advocated by Shuttleworth,[7] who, having collected some red patches on the Grimsel above the line of perpetual frost, detected vast numbers of microscopic animals of exceeding minuteness and surprising agility. Agassiz views this as an animal product, and holds the opinion expressed by others, that the *Protococci nivalis* are the ova of

[1] Ramond. [2] Agardh. [3] Sommerfeldt. [4] Voy. dans les Alps, tom. iii.
[5] Connex. of Phys. Sc.; Peschier,—Bib. Univ. Dec. 1819.
[6] Ann. of Philos. vol. xv. p. 419. [7] Ed. New Phil. Jour. No. 57, col. plate.

a species of rotiferous animalcule, the *Philodina roseola* (Ehren.). Professor Mayen considers that the *protococci* of red snow are true infusoria ; that the *P. viridis* is the *Euglenia viridis* of Ehrenberg, and the *P. nivalis* is identical with the *Euglenia sanguinea* (Ehren.) ; the *Enchelides sanguinea* and *Pulvisculus* of others.[1] Dr Vogt detected by the microscope six different organisms on the Aar glacier. The *Rotifer*, a variety of *Philodina roseola* (Ehren.), was abundant. He found eggs of a deep red hue in various stages of development. Under the glacier of Rosenlain, near Guttannem, he met with these ova, together with the *Philodina*,[2] in the crevices of a polished rock. Carpenter,[3] however, from personal examination, adopts the view of their vegetable origin. Martins, in the union of both, gives probably the correct explanation, that *this product is a vegetable cell, enclosing fluid in which multitudes of infusoria find a nidus and support.*

216. Analogous to this phenomenon is that vulgarly called *snow-mould*, a name given to various microscopic fungi of the *antenarias, mucors,* &c. Of these, Hienemann has termed one genus discovered by Thieneman in Iceland, the *Chionyphe*, and since then, others have been found in Germany near Dresden, *e. g.* the *Lanosa nivalis*[4] of Professor Unger, which has the peculiarity of being produced *beneath* the snow, and is found to be exceedingly destructive to vegetation : it occurs in patches, tinging the snow red from the colour of its pores.

217. Sleet is the mixture of rain and snow or small hail occurring during variable and gusty weather. It does not require particular notice, as the meteors of which it is composed have been already considered.

218. The *glacier* forms one of the noblest features of Alpine scenery ; whether viewed in the magnitude of its mass, or *débouchure* of its waters, rolling at once a resistless torrent, or contemplated in its hore antiquity, its dangers, and desolations,—the mind is awed and astonished. The glacier is a vast accumulation of ice, occupying the space between the

[1] Newman's Phytologist, July 1841. [2] Bib. Univ.; Microscop. Jour. No. 6.
[3] Princip. of Gen. and Compar. Physiol. 8vo, 1841, p. 76.
[4] Gard. Chron. 1846.

sides of some alpine chain, or lying in a mountain gorge. The chief mountain range is generally the region of perpetual congelation ; on either side, minor parallel chains recede from the parent mass, their declivities are generally fertile, and the cultivated valleys are watered by the mountain streams. Such is a general outline of the physical features of those alpine mountains, where, in the gorges between the minor ranges and the central chain the glacier is found. Its upper boundary is met by the lowest limit of perpetual snow ; it stretches along the ravine till it reaches the cultivated land, where it terminates in a wall of ice, bordered by *débris* pushed before it in its descent. On the upper confines of the glacier, we meet with snow in a dry or partially consolidated state. This is the *firn* of the Swiss, or the *névé*, which is smooth, concave, and of a dazzling whiteness. The surface of the glacier is convex, broken with fissures, and traversed by clefts in the direction of its motion,—for this immense body of ice is never at rest. The summer's sun melts its surface, giving rise to an impetuous stream which rushes down the valley.

219. These collections of ice are of enormous magnitude. Thus, the Glacier des Bois which terminates in the Mer de Glace, is estimated to be fifteen miles long and three in breadth, while its depth, according to Saussure, varies from 80 to 600 feet ; and the Unter-aar-gletscher, to the west of the Hospice of the Grimsel, is about eighteen miles long, and from three to four broad. Those around Monte Rosa, the Cervin, and that at the foot of the Finster-aar-horn in the Bernese Alps, are truly magnificent objects. The last, with its thirteen minor glaciers, covers an extent of 125 square miles! The total number among the Alps is supposed to be between five and six hundred ; and in Switzerland, Savoy, Piedmont, and the Tyrol, they are estimated to cover an area of nearly 1500 square miles. The Maladetta glacier in the Pyrenees, and the Justedals Eisberge in Norway, are also of vast magnitude. Von Buch[1] observes, that while the church of Justedal, in the middle of the valley, is only 680 feet above the ocean-level, the foot of the enormous glacier there is estimated at a height

[1] Gilbert's Annalen. tom. xli. 1812.

of 1592 English feet; a moraine of gigantic dimensions is interposed. The Klofa Jokül in the eastern part of Iceland, is computed by Henderson[1] to cover, with its ice and snow, a superficies of 3000 miles. Those of Spitzbergen and Greenland in the northern polar circle, and of Victoria Land in the antarctic regions, are immense, almost beyond conception. Of the latter, Sir James C. Ross[2] thus writes, when, on his second voyage in January 1841, he first saw land with mountains rising seven and ten thousand feet above the ocean,—"the glaciers that filled their intervening valleys, and which descended from near the mountain summits, projected in many places several miles into the sea, and terminated in lofty perpendicular cliffs."

220. Much caution is required by travellers when crossing those glaciers which have a snowy covering. Melancholy accidents often result from want of care in this respect. It is mentioned by M. de Luc, that the guides had cautioned M. Escher de Berg against separating himself from his companions upon the glacier, but in his desire to advance, observing near the top of the glacier two chamois-hunters, he left the guides and hastened to reach the huntsmen. In a moment he disappeared, and was precipitated to the bottom of a frightful chasm, meeting with instantaneous death from the compression of his body in a narrow portion of the *crevasse:* it was in 1791, near to Trient, not far from the Col de Balme. On the 7th of August 1800, M. Eschen, a young Danish traveller, neglecting the counsel of his guides, met a similar fate on the Buet. He left Servoz the evening before, with a companion, and slept at the Chalet of Villy. The next morning they ascended the Buet with the guide. Arriving at the glacier, M. Eschen, then some hundred paces in advance, suddenly disappeared. He was discovered in the evening in a cleft of the ice, in an upright posture, 100 feet below the surface, his arms raised and entirely frozen.[3] Such, too, was the fate of M. Mouron of Vevay, who, in 1821, adventured on the Eiger glacier flanking the northern side of the Viescherhörner, to

[1] Resid. in Iceland. [2] Voy. of Discov. 2 vol. 8vo, 1847.
[3] Ebel,—Manuel du Voyageur en Suisse, traduit de l'Allemand, ii. 239.

prosecute some scientific researches. He was near the Heisseplatte, overlooking one of the much-dreaded fissures, when the alpenstock gave way, and he was cast to the bottom. His body was sought for, but for twelve days in vain; at last it was discovered in the bottom of the *crevasse*, and drawn out by the guide Burguenen, who nearly sacrificed his own life in unsuccessful attempts, through mephitic air—the third time he was the bearer of the body, which was interred at Grindelwald. Ebel relates the case of a shepherd who, tumbling down one of these clefts in the ice, fell in the vicinity of of a stream which flowed below; following its course, he succeeded in effecting his escape with only a fractured arm. The late Hon. J. E. Murray[1] gives an account of the loss of a guide on the Maladetta glacier. Bodies have been found in these awful rents, lying on a projecting ledge or suspended in the dismal gulf, showing that the unhappy sufferer must have had a lingering death.

221. The glacier, it has been said, is always in motion. Its progression is in the direction of the gorge, but the rate of its descent is not fully ascertained; probably this is varied by the physical features of the valley. M. Hugi endeavoured to calculate this amount on the glacier of the Aar, and for that purpose, in 1827, he erected a rude hut, now in ruins, at the foot of the Im Abschwung, the last projecting promontory of the *moraine* separating the *Ober* and the *Unter-aar-gletscher*, to the west of the Hospice of the Grimsel; in 1840, it had advanced 4600 feet from its original position. The alterations in the relative position of the blocks of granite and finger-posts were no less remarkable; thus, two masses of rock, once 8 feet apart, were in 1836 separated 18 feet; and a finger-post, which had advanced equally with the hut, became farther removed from it by a distance of 760 feet, showing a double motion. Near to this spot is the retreat of Agassiz and Desor, known as the *Hôtel des Neuchâtelois*, 7500 above the sea. The destructive power of the glacier in its progression, was exhibited in Norway about the middle of last century. The *Jis-Braeer*, as the glaciers are there designated, reposing in

[1] Summer in Pyrenees, vol. i. p. 292.

the valleys of the Justedals Eisberge, on the northern side of Sognefiord, advanced upon the fields of the inhabitants so that they found themselves unable to pay their taxes ; but their complaint was discredited, and surveyors were appointed to make triennial measurements of the distance between the foot of the glacier and Milvirsdal. Before the measurement was repeated, the ice had covered both fields and houses ; and the commissioners, on paying their second visit to the spot, found the inhabitants gone, and their property buried below the Jis-Braee.[1]

222. Occasionally an unexpected change takes place, quite distinct from the motion referred to. A remarkable movement of this kind was experienced by the priest of Grindelwald and his companion, a chamois-hunter, upon the Eismeer of Grindelwald, in the Bernese Alps,—one of the grandest and awfully wild glaciers in Switzerland. They had been crossing the ice and were now resting, when they found the glacier suddenly move. A sound like thunder fell upon the ear, and forthwith everything was in motion,—rocks, before motionless, rolled about ; the crevasses shut with dreadful noise, and fresh fissures opened. The glacier seemed to move *en masse* several yards in advance. It was the work of an instant ; the dreadful convulsion passed ; silence again reigned, and the shrill call of the marmot alone broke the solitude !

223. This leads us to mention that the crevasses of the glacier are of two kinds, distinct in appearance, and dissimilar in origin. One of these, running *across* the glacier, has been denominated the *day-chasm*, and the other, extending *along* the glacier, has been called the *night-chasm*, from the supposed periods of their formation. The *day-fissures* arise from the splitting of the ice under the influence of the sun and certain winds, giving rise to the irregular motion described in the last paragraph ; their dimensions are various, from inches to yards, and their depth varies with the angle of their sides, for they are like a wedge. The *night-fissures* resemble Gothic arches, or fairy palaces of exquisite beauty

[1] Thaarup's Magazin fur Statistik, 1802; Von Buch,—Gilbert's Annalen der Physik, 1812.

from the clear blue ice, studded here and there with stalactites of the same material. They are met with at the upper part of the glacier, while the crystal vaults which discharge the chill waters in a noble stream are found at its base. M. Hugi thus describes the formation of one of the former fissures:—"When I was once walking upon the glacier of the Lower-Aar, at 3 P.M., and the weather being very hot, I heard a peculiar noise. Advancing directly towards the spot whence it proceeded, I had hardly walked thirty or forty paces before I felt that the whole icy mass trembled under my feet. The trembling soon ceased and then began again, continuing by starts. I quickly discovered the cause. The ice was splitting and forming a chasm. Before my eyes it split suddenly over a space of twenty or thirty feet in length, so rapidly that I could not keep up with it. Then it appeared to cease, or rather the rent proceeded more slowly until the trembling returned, and the splitting proceeded at an accelerated rate. Several times I advanced to the end of the new-formed rent, and laid myself down on the ice. The chasm opened under my very face, and I experienced a considerable shock. In this way I followed the splitting of the ice for nearly a quarter of an hour, until it terminated in the *moraine*. When the chasm was forming, its opening was about an inch and a half wide; afterwards it contracted somewhat, so that at no place was it wider than an inch. The depth I estimated at about four or five feet. I observed, at the same time, that the splitting downwards still continued, but very slowly. After some days I again visited the place. I found that the opening had increased to the breadth of six inches, but did not succeed in ascertaining the depth. At a distance of about twelve feet another rent had been formed, which extended exactly parallel to the first, and was about six feet deep."

224. The progression of the glacier, according to Professor Forbes of Edinburgh, is nearly unform during night and day, and it is *fastest towards the centre*, an opinion at variance with that of M. Agassiz. The longitudinal motion of a point on the Mer de Glace for four consecutive days, was observed by Forbes to be 15.2, 16.3, 17.5, and 17.4 inches respectively:

this motion takes place in the glacier *en masse.* On the 28–29th of June, from 6 P.M. to 6 A.M., the motion was 8 inches, and from 6 A.M. to 6 P.M., 9.5 inches; on the 29–30th from 6 P.M. to 6 A.M., it amounted to 8.5 inches, and from 6 A.M. to 6 P.M. it was 8 inches. In the Mer de Glace, the higher part of the Glacier de Lechaud was observed to move slower than the lower part near the Montanvert, as 1 to 2. The motion was ascertained to be continued during winter (1842–3); up to December it nearly averaged the summer's velocity; from December to February its rate of progression diminished about one-fourth; after that month it resumed its former speed. It was found likewise, that the surface of the Mer de Glace was depressed more than twenty-four feet from the 26th of June till the 16th of September. The surface of the glacier of the Aar has been observed to loose three feet in as many weeks, under the solar rays.

225. The glacier is thus constantly undergoing a process of destruction, but at its upper boundary a plan of renovation, not fully understood, supplies the waste. The snow which lies above the glacier is no doubt the source whence this supply is found, but *how* the change from the névé to the glacier—often hundreds of feet thick—is effected, must wait the result of farther observations. It is supposed to arise from the influence of the sun in melting portions of the snow: the resulting water percolates the loosely aggregated particles, displacing part of the air occupying the interspaces, and this disengagement is facilitated in the higher regions by the low barometric pressure of the ambient air; the water freezes as it sinks nearer to the earth, especially under the influence of the cold night-air: the following day the process is resumed.

226. It is only very recently, through the zeal of Professor Forbes, that the correct theory of the progression of the glacier has been propounded. Saussure was satisfied with ascribing the phenomenon to gravitation, aided by the fusion of the ice in apposition with the ground; it was thought that the weight of snow above, would counterbalance the resistance offered by friction, to the passage of the enormous mass. To this theory such objections and difficulties appeared that

Agassiz[1] and Charpentier advanced another hypothesis, or that of dilatation. Very recently M. Agassiz[2] appears to have abandoned this hypothesis and adopted the plastic theory of Forbes. There was still another explanation of the phenomenon offered,—the hydrostatic pressure of the water enclosed, and that flowing between the glacier and its bed, from obstruction to its passage. This theory was proposed by Mr R. Mallet,[3] but it is not borne out by facts.

227. The *dilatation theory* may be thus explained. Water having entered the crevices or capillary fissures, either by the fusion of the surface of the ice, or from some other cause, is supposed to be rapidly frozen, thawed and solidified alternately, producing an internal swelling or dilatation of the glacier, sufficient for the phenomenon in question. Gravitation is made subservient merely to the guiding of the glacier, and the thawing of the ice at the earth's surface is excluded from participation in the theory. This explanation does not bring conviction to the mind; several objections are insurmountable. Professor Forbes has shown that it has no foundation, for the facts upon which its stability depends are hypothetical. He has proved that the motion takes place during both summer and winter, which upon this theory would not be the case; besides, he has experimentally demonstrated that the cold of the summer's night does not penetrate the *mass*, being confined by virtue of the laws of insensible caloric to a very small depth. This leads us to explain the *viscous theory* of Forbes.[4]

228. To understand the viscous theory, we must first acquaint ourselves with the *internal structure* of the glacier. Professor Forbes had frequently visited the alpine regions of Switzerland, but it was not till the 9th of August 1841, that he paid a visit to the lower glacier of the Aar, and in the summer of

[1] Agassiz,—Jameson's Jour.

[2] Agassiz,—"The quantity of water which gorges the glacier, seems to be the cause of its motion, in consequence of the hydrostatic pressure which it exerts on the mass."—Bib. Univ.; Jameson's Jour. Jan. 1846. vol. xl. p. 154, Letter from Prof. Forbes.

[3] Seventh Rep. Brit. Assoc. 1837, p. 64.

[4] Trav. through Alps of Savoy, 4to, 1843.

the following year, at the close of his Professorial duties in Edinburgh, he returned to prosecute his investigations, selecting for that purpose the Mer de Glace. Referring to the former of these visits to the glaciers, he says,—"It is surprising how little we see until we are taught to observe. I had crossed and recrossed many glaciers before, and attended to their phenomena in a general way; but it was with a new sense of the importance and difficulty of the investigation of the nature and functions, that I found something to remark at every step which had not struck me before. In the course of this walk of eight or nine miles over this glacier, I noticed in some parts of the ice an appearance which I cannot more accurately describe, than by calling it a *ribboned structure*, formed by thin and delicate blue and bluish-white bands, or strata, which appeared to traverse the ice in a *vertical* direction, or rather which, by their apposition, formed the entire mass of ice. The direction of these bands was *parallel to the length of the glacier*, and of course, being vertical, they cropped out at the surface." The Professor goes on to observe, that "in the neighbourhood of the *moraine* and the walls of the glacier this structure was most apparent. It penetrates the *thickness* of the glacier to great depths. It is an integral part of its internal structure." This veined structure is observable in very small specimens of the ice. True horizontal stratification is found in the névé, but not in the real glacier; the one may be superimposed upon the other, however. As Mr Forbes pursued these inquiries, he was one evening, when the sun's rays presented the glacier in a new aspect, struck with the appearance of a number of discoloured lines upon its surface. These, which he has aptly called *dirt-bands*, are formed by the retention of sand in the more porous portions of the ice. By them he was better able to observe the direction of the veined structure, and he found that though always nearly vertical, these lines are not constantly parallel, but diverge from the centre in a series of curves, the sides of which when prolonged are sometimes parallel with the sides of the glacier. Noticing that the mass of ice is traversed by a multitude of capillary fissures which admit to a great depth the surface water, and

impart a degree of flexibility to the glacier ;—together with the existence of the structure described, which could be traced from the névé to the termination of the glacier,—the idea struck Professor Forbes, that the glacier might be considered as a viscous or plastic body. "A glacier," says he, "is an imperfect fluid or viscous body, which is urged down slopes of a certain inclination by the natural pressure of its parts." Thus may be explained the motion and internal structure of the glacier, for the pressure of the parts being unequal, and the velocities of the different portions dissimilar, the veined or *ribboned structure* and the curving *dirt-bands* will be generated.[1]

229. There is another curious fact connected with the glacier, which we would describe in the words of Forbes.[2] "The surface of the glacier has for the most part the same appearance as to the variation of level, the occurrence of moraines, the system of complex crevasses, and the formation of superficial watercourses, in any one season as in another. These phenomena, then, are determined by the form of the bottom and sides of the rocky trough in which the glacier lies, and by its slope at the spot. Just as in a river, where the same molecules of water form in succession the deep still pool, the foaming cascade, and the swift eddy, all of which maintain their position with reference to the fixed objects round which the water itself is ever hurrying onwards." We have said that the surface of the glacier is convex, so is that of a swollen stream.

230. The inclination of the glacier to its bed is very various ; thus, that of Aletsch averages 3°, while those of the Dent du Midi are inclined 45°. Their advance into the valleys is likewise inconstant ; the higher their source the nearer do they approach the plains.

231. The colour of the glacier changes as the traveller approaches the névé. At the lower part and on the surface generally it is dingy-looking or white, and white mixed with

[1] Vide recent vols. Edin. New Phil. Jour. *passim ;* Edin. Rev. Ap. 1842 ; Nor. Brit. Rev. Aug. 1844.
[2] Trav. p. 78.

blue. The mass presents a fine blue, with occasionally a green; the fissures are of a rich ultra-marine hue.

232. A sudden flow of air through the crevasses of the glacier, caused by changes of temperature in the atmosphere, is often experienced. This is the *wind of the glacier*—gletschergeblase.

233. The *moraine*[1] is the collection of débris met with at the foot and sides of the glacier, running parallel with its middle and the lateral surfaces,—*moraines médéanes* or *guffer-linéen*, and *moraines laterales* or *gandecker*. As fragments of rock become detached from the sides of the gorge, they find a temporary resting-place upon the ice, till, carried down with it in its descent, they are precipitated from its surface at its termination. When glaciers from opposite valleys meet, the moraines become united in their centre of union. Examples of this are found in the glaciers of the Aar and Monte Rosa. When the ice recedes, through the fusion of its lower margin, it leaves behind the débris of the medial and lateral moraines, termed the *terminal moraine*. These terminal moraines are often of great height, and occasionally several parallel ridges are met with; they become registers of the maximum extent of the glacier into the valley in the direction of its motion, while the erosions on the lateral surfaces of the gorge indicate its greatest thickness. It has been observed by Charpentier,[2] that the moraine is not stratified, as would have been the case had its contents been deposited from water, but consists of a confused and promiscuous heap of débris left in the spot to which it has been transported by the glacier. The geological structure of the rocks on the confines of the glacier produces a marked effect upon the size of the moraine. Terminal moraines having been observed at great distances from existing glaciers, some interesting geological speculations have arisen, upon the transporting of erratic blocks by glaciers and icebergs.[3]

[1] *Synon. Trockne-muren*,—Tyrol; *Guffer*,—Germ. Cantons; *Jokülsgiärde* or Yokülsgiärde,—Iceland.

[2] Ann. des Mines, tom. viii.

[3] Agassiz,—Bib. Univ. No. 24, 1837, &c., Lyell's Geology. It is mentioned by Professor Forbes, that from notes of Lectures taken in 1827, while attending the University of Edinburgh, Professor Jameson, even then, taught the transporting influence of ice upon erratic blocks,—*Physical Atlas*.

234. The curious appearances termed *tables des glaciers*, are well exhibited upon the Aar-gletscher. This phenomenon occurs when *large* rocks fall upon the ice, guarding from the solar beams that portion of the glacier on which they rest. The surface around gradually melts away, but these rocks remain upon their original level, looking as if supported upon a pedestal. A very remarkable one was seen upon that glacier by Professors Hugi and Agassiz, some years ago, when these gentlemen were making observations upon its motion. A block of granite measuring 26,000 cubic feet, originally enveloped in the névé, was found elevated upon two icy pillars so high that they could shelter below it. When a stone of *small* dimensions thus falls, an opposite effect is produced; for, absorbing the solar heat, its temperature rises above that of the ice, which melts, and thus the foreign body sinks below the surface of the glacier.[1]

235. The melting of the glacier gives rise to springs in their vicinity, which are often periodic; the water percolates through the rocks whose geological structure is permeable to that fluid, and appears in the valley below. Bischoff remarks, that the periodic springs at Leuckerbad, near the Lötsch glacier on an adjoining mountain, are observed to flow and dry up, three days after the melting of the ice has begun, and the cessation of the flow of water from its surface. To the physical geographer and geologist, it is not a little interesting to know that the warmest of the thermal springs of Central Europe are those met with beside the glaciers,—*e. g.* at Mont Blanc, and at Leuck, points where the separate formations of the Westphalian and Valais Alpine systems cross.

Before closing our description of the glacier, we would notice the curious discovery made in 1828, on Etna, of a mass of ice covered by a bed of lava, although it belongs rather to physical geography and geology. The summer of that year was remarkably hot, and the supplies of snow and ice were cut off from the inhabitants, who had become accustomed to

[1] Vide Saussure,—Voy. dans les Alpes; Agassiz,—Etudes sur les Glac.; Hugi,—Naturhist. Alpenreise; Forbes,—Travels; Desor,—Bib. Univ.; Jameson's Jour.; Charpentier, and others.

consider these as necessaries of life ; inquiries were therefore made to Signor Gemmellaro, "in the hope," says Sir C. Lyell,[1] "that his local knowledge of Etna might enable him to point out some crevice or natural grotto on the mountain, where drift snow was still preserved. Nor were they disappointed ; for he had long suspected that a small mass of perennial ice at the foot of the highest cone was part of a large and continuous glacier covered by a lava current. Having procured a large body of workmen, he quarried into this ice, and proved the superposition of the lava for several hundred yards, so as completely to satisfy himself that nothing but the subsequent flowing of the lava over the ice could account for the position of the glacier." This interesting spot is near the Casa Inglese, on the south-east side of the cone.

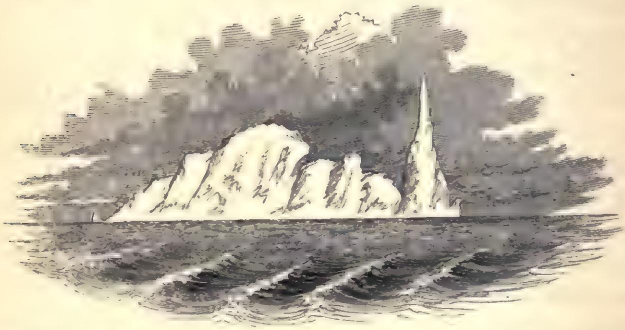
Regarding the probable origin of this phenomenon, Sir C. Lyell goes on to observe :—"We may suppose that, at the commencement of the eruption, a deep mass of drift-snow had been covered by volcanic sand showered down upon it before the descent of the lava. A dense stratum of this fine dust mixed with scoriæ, is well known to be an extremely bad conductor of heat ; and the shepherds in the higher regions of Etna are accustomed to provide water for their flocks during summer, by strewing a layer of volcanic sand a few inches thick over the snow, which effectually prevents the heat of the sun from penetrating." On the authority of Lieutenant Kendall,[2] Deception Island, in New South Shetland, is chiefly composed of alternate layers of ice and volcanic ashes.

236. The iceberg is the creation of many ages ; originally a prodigious glacier reposing in the valley of some polar mountain, it has been loosened from its hold and tumbled in the ocean. Dreaded by the navigator, it floats a fantastic and majestic island. In Spitzbergen[3] and Greenland the iceberg is seen in all its grandeur and its terror. "Frost," says Pennant, "sports with these icebergs, and gives them majestic as well as singular forms. Masses have been seen

[1] Princip. of Geol. vol. ii. p. 233. [2] Jour. Roy. Geogr. Soc. i. 64.
[3] Scoresby,—Arct. Reg. vol. i. ; Latta,—Ed. Phil. Jour. iii.

assuming the shape of a gothic church with arched windows and doors, and all the rich drapery of that style, composed of what an Arabian tale would scarcely dare to relate, of crystals of the richest sapphirine blue ; tables with one or more feet ; and often flat-roofed temples like those of Luxor on the Nile, supported by transparent columns of cerulean hue, float by the spectator."

Captain Horsburgh mentions having met with icebergs like church spires, from 250 to 300 feet high, off the Cape of Good



Iceberg seen off the Cape of Good Hope, April 1829, in S. lat. 39° 13′, and E. long. 48° 46′, by Captain Horsburgh.

Hope, in sea where there was no sounding.[1] We have the testimony of another witness to a similar fact,—"Islands of ice," says Dalrymple,[2] "have been seen sometimes, though rarely, by our ships in doubling the Cape." Captain Weddell[3] fell in with one in the antarctic ocean, which rose to a height of 180 feet, and was cracked from the water-mark to the summit which overhung the rest. "We had," he says, "the appalling sight of the overhanging mass immediately over our quarter-deck, with the fearful sensation that if our masts came in contact with it, the projecting part would fall upon us and sink both vessels. Our escape was caused solely by our having a large piece of ice between us and the ice-island, which prevented us touching it." This navigator, on February 10. 1823, in S. lat. 64° 15′ and W. long. 30° 46′,

[1] Phil. Trans. 1830.
[2] Mem. on Southern Ocean, p. 17.
[3] Voyage towards South Pole.

met with ice so incorporated with black earth that it was mistaken for *terra firma.* This circumstance recals to mind an interesting observation of Sir J. C. Ross, on his first antarctic voyage, illustrating the drifting of stones through this medium. It was in the year 1839, when an iceberg was discovered with a block of rock imbedded in the ice, in S. lat. 61°, and 1400 miles from the nearest *known* land, though perhaps not more than 100 from land yet unseen. The portion visible was about 12 feet high and 6 wide, and nearly 100 feet above the water mark.[1] In Davies' Straits, where there is deep water, icebergs have been met with having an area of nearly six square miles, and rising to the altitude of about 600 feet. Near to Whale Island, in this strait, in N. lat. 69°, Sir J. C. Ross[2] met with icebergs rising 200 feet above the océan, and having a proportionate bulk, in June 1848. As it may be experimentally shown, that floating ice sinks seven-eighths of its entire mass under water, it follows that an iceberg, rising only a few fathoms above the ocean, must be immense. Sir John Franklin,[3] however, observes, that these masses of ice are frequently magnified to an immense size, through the illusive medium of a hazy atmosphere, and on this account their dimensions have been sometimes exaggerated by voyagers. It should be remembered too, that icebergs are often stranded; thus, Sir John Ross saw several aground in Baffin's Bay, in water of 260 fathoms. One there, was computed to weigh 1,292,397,673 tons; its dimensions were 51 feet high, 12,507 feet long, and 11,067 feet broad,—(1 mile lineal = 5,280 feet). Captain Beechey computed the weight of one of small size which he saw to fall from a glacier in Spitzbergen, at 421,660 tons. Graah,[4] the recent Danish voyager, whose success in reaching a high latitude under the most unaccountable want of every requisite for such an expedition, is beyond praise,—with a slender boat covered with skins, and women as his rowers,—with inadequate food, and

[1] Voy. of Discov.; Jour. of Royal Geogr. Soc. vol. ix. 526, 529.

[2] Letter dated 29th June 1848,—*Record* of Sept. 21. 1848.

[3] Narrative, 3d ed. vol. i. p. 18.

[4] Undersögelses-Reise til Östkysten af Grönland, 1828–31: Copenhag. 1832,—Macdougall.

sometimes none at all,—with nothing to administer relief when sick,—with little more than his instruments for determining his geographical position,—and all this in the 19th century, by an enlightened government !—this enterprsing officer estimated the magnitude of an iceberg on the east coast of Greenland, at a height of 120 feet, 4000 feet in girth, and containing 900,000,000 cubic feet.

The *Great Western* steam-ship, during its transatlantic voyage in April 1841, passed within sight of 300 icebergs, the largest of which was nearly 100 feet in height, and three fourths of a mile in length ; and was close upon an ice island above 100 miles long, running from E. to W., between lat. 42°–43°, and long. 48°–50°. The thermometer fell to 28°F., and the temperature of the ocean to 25°, in the immediate vicinity of the icy mountain. Upon the 19th of the same month, the *William Brown* of Philadelphia, was lost by striking on an iceberg in N. lat. 43° 30′, and W. long. 49° 39′. In March 1826, the *Ajax*, in N. lat. 44° 30′, and W. long. 42° 44′, found herself for 300 miles close to ice-islands and icebergs; once they were so near, that the captain and part of the crew *walked* upon the ice.[1] On the 4th of March 1847, during the homeward passage of the *Cambria*, ice was met with in very large blocks, which choked the wheels and injured the paddle-boxes. On May 21st, in the same year, the *Eulalia* was cut down by an iceberg, in lat. 42°, and long. 52° ; twenty persons perished. In the summer of 1848, in N. lat. 48°, and W. long. 49°, the *Blonde* of Greenock met with an iceberg a mile in length and 600 feet in height. Besides the cold which is experienced in the neighbourhood of these icebergs, Foery[2] observes that they " give to the winds which blow a harsh and chilling influence."

237. Icebergs are rarely, if ever, met with between lat. 40° N. and 36° S. ; one, however, is said to have been observed off Antigua.[3] In the Atlantic, the normal longitudinal limits of icebergs are between W. long. 42° and 52° ; once in 1817,

[1] Clim. of Unit. States.

[2] Unit. Serv. Jour. ii. 716-720 ; Quart. Rev. No. 36.

[3] Unit. Serv. Jour. 1829, ii. 718, note.

ice was seen to the east of the former parallel, in long. 33°. Von Buch[1] observes that in Europe, the most southern part where a glacier descends to the sea-level, and thereby generates the iceberg, is in Norway, in N. lat. 67°; in the southern hemisphere, however, this point is met with, according to Darwin,[2] in S. lat. 46° 40°.

238. Icebergs are known to split into fragments without an apparent cause, accompanied by a sound like that of thunder; and in the case of the collision of two, with the production of light. This phenomenon M. Becquerel attributes to electricity. A parallel phenomenon was observed in December 1819, on the the descent of the Weisshorn glacier upon the village of Randa; when the ice and snow struck the inferior mass of the glacier, during the night, a light flashed, and almost instantly disappeared.[3] Icebergs are observed to present different colours and shades of blue. Scoresby[4] mentions, that when newly fractured, the edges glisten with a greenish-blue, approaching to emerald-green, but, when long exposed, they exhibit the appearance of a marble cliff.

239. The curious circumstance of the iceberg being capped with mist is sometimes witnessed. This is owing to the evaporation from its surface, and the low temperature of the surrounding air,—for we have mentioned that both the atmosphere and ocean indicate a decline of heat in the vicinity of an iceberg. At other times the entire iceberg is enveloped by the fog, and then becomes one of the most formidable weapons of destruction to the vessels navigating the polar seas.

240. We would conclude this portion of our subject with a brief notice of some of the physical properties of ice not already described. Its specific gravity is less than that of water, and its refractive power is 1.3 below that fluid. When slowly conglaciated, it assumes the form of regular crystals. Haüy supposed the primary form to be octahedral; and Scoresby,[5] Romé de Lisle,[6] and D'Antic,[7] sometimes found crystals of

[1] Trav. in Norway. [2] Journal. [3] Bib. Univ. Fev. 1820.
[4] Arct. Reg. vol. i. p. 104. [5] Mem. Wern. Soc. Edin. vol. ii. part 2.
[6] Crystallographie, tom. i. p. 4. [7] Jour. de Phys. 1788.

ice composed of two four-sided pyramids. Hericaut de Thury[1] met with them in drusy cavities in the subterranean glacier at Fondeurle, in the south of France, presenting hexahedral prisms, with the terminal surface covered with striæ parallel to the faces of the crystal, and occasionally in the form of triangular prisms ; in no case could he discover them with pyramidal summits. Hexahedral crystals of ice have been found also by Hassenfratz,[2] and Scoresby.[3] These hexahedral prisms, however, are secondary forms. On the 3d of January 1821, Dr Clarke[4] found regular rhombic crystals, many of which were more than an inch in length, at Cambridge ; the angles measured by Carangeau's goniometer were 120° and 60°; these angles were preserved after it thawed. Some years previous to this interesting observation of Dr Clarke, Sir David Brewster[5] had referred the primary form of ice-crystals to the rhomboidal or pyramidal systems of Mohs, in consequence of the optical properties of ice. By transmitting polarized light through plates of ice formed on standing water, in a direction perpendicular to their surface, he obtained concentric coloured rings, with a dark rectangular cross passing through their centre,—rings similar to those seen along the axis of zircon.[6]

[1] Ed. Phil. Jour. vol. ii. 81 ; Jour des Mines, tom. xxxiii. p. 157.
[2] Jour. de Phys. Jan. 1785.
[3] Mem. Wern. Soc. Edin. vol. ii. part 2.
[4] Mem. Cambr. Phil. Soc. vol. i. p. 209.
[5] Werner. Mem. vol. iii. p. 348.
[6] Phil. Trans. 1818, 211 ; Edin. Encyc. vol. xi. 637 ; Encyc. Brit. 7th ed. xvi. 480.

CHAPTER X.

241. The Rainbow; early speculations upon its cause. 242. Solar spectrum. 243. Requisites for production of the rainbow. 244. Various arcs observable. 245. Theory of the primary rainbow. 246. Explanation of the secondary bow. 247. Dimensions and positions of the several arcs. 248. Supernumerary or supplementary bows. 249. Rainbows from reflexion. 250. Composed of polarized light; Peculiarities in the spectrum; White rainbows. 251. Why not seen at noon in summer. 252. Lunar rainbows. 253. Instances recorded. 254. Marine and other rainbows; Iris of cascades. 255. Coronæ and halos. 256. Remarkable lunar halo seen by Humboldt. 257. Solar halos. 258. May be artificially produced. 259. Glories, or Anthelia. 260. Analogous aerial meteors. 261. Theory of these meteors. 262. Parhelia. 263. Appearances in ancient times, and middle ages. 264. Remarkable one seen by Hevelius; and subsequently. 265. In present century. 266. Theory of the phenomenon. 267. Explanation of the concentric solar circles. 268. Of the circumzenithal arcs. 269. Of the great parhelic circle. 270. Of the mock-images. 271. Paraselenæ. 272. Columns of light at sunrise and sunset; Blue suns.

"A Bow,
Conspicuous with three listed colours gay;
.... What mean those coloured streaks in heav'n,
Distended as the Brow of God appeased?
Or serve they as a flow'ry verge to bind
The fluid skirts of that same wat'ry cloud,
Lest it again dissolve and show'r the earth?"
Paradise Lost, xi. v. 865–883.

"My lord, they say, five moons were seen to-night."
King John, act iv. sc. 2.

241. So early as the 16th century, a scientific explanation of the rainbow was proposed by Maurolycus of Messina, but the theory was correct only so far as to attribute the phenomenon to the refraction of the sun's beams, by the rain-drops falling from the cloud upon which the arch is projected. About two centuries before, a Dominican Friar named Theo-

doric anticipated Maurolycus. The manuscript of Theodoric, brought to light by Venturi,[1] bears date 1311. Fleschier of Breslau,[2] in 1571, made a nearer approach than any of his predecessors, in supposing that the solar ray suffered two refractions from the rain-drop, but he erred in thinking that the decomposed beam reached the eye by reflexion from *another* drop. The nearest approach to the true explanation of its cause was stumbled upon by Antonio de Dominis,[3] the fickle archbishop of Spalatro in Dalmatia, and published at Venice in 1611. De Dominis was led, by accident or design, to experiment with a sphere of glass filled with water, which resembled, as he thought, a drop of rain, only of larger dimensions. Placing the vessel in a proper position regarding the sun and the eye, he found similar colours produced and disposed in an order similar to the rainbow. He theorised, and though in some particulars erred, yet he rightly conceived that the phenomenon depended upon the refraction and reflexion of the solar pencil in the *same* drop.

242. If a solar ray impinges upon a piece of glass of a triangular form, technically called a *prism*, and is projected upon a white screen in a dark room, it will be separated into several different colours, viz., red, orange, yellow, green, blue, indigo, violet; three of which, red, yellow, and blue, may be considered primary. The relative position of these hues is always the same; the red or least refrangible ray, appearing nearest to, or at the smallest angle with, the line in which the sunbeam falls upon the prism; and the violet, or most refrangible ray, being bent from that straight line at the greatest angle. A pencil of white light is thus found to be composed of several rays of different hues, possessing independent properties; and although the seven mentioned are the only ones which in ordinary circumstances appear, at least two others may be proved to exist. Thus, if the spectrum be received upon a sheet of turmeric paper, one of a lavender colour appears beyond the violet; and if viewed through a cobalt-blue glass when projected in the usual manner, a crim-

[1] Ann. de Ch. tom. vi. [2] De Iridibus Doct. Aristot. et Vitellionis.

[3] De Radiis et Lucis. Antonio de Dominis was made by James I. the Dean and first Prebendary of Wolverhampton.

son ray,—the extreme red of Herschel,—becomes visible below the red. The point of greatest illumination is in the yellow ray. In the phenomenon of the rainbow,—

> "The airy child of vapour and the sun,"

the rain-drop represents the prism, and the dark back-ground the screen upon which the spectrum is projected.

243. The co-existence of the following circumstances is required for the production of the rainbow:—the sun's altitude must be less than 45°; the solar rays must impinge upon the falling rain; and the observer must be interposed. A line from the sun to the centre of the arc passes through the head of the spectator, consequently each views his own rainbow.

244. In addition to the *primary rainbow,—hauptregenbogen,*—which has the red external, one of larger dimensions, but fainter, is found to be concentric; this is the *secondary rainbow,—nebenregenbogen,*—in which the red is internal. Above the prismatic arc, the sky is deeply darkened, especially when the sun is low and the meteor vivid; this arises from the fact that the rain-drops *below* the rainbow dart to us the rays reflected posteriorly, faintly illuminating the segment under the arc, while those from the drops *above* the bow, do not reach the eye. Theory leads us to look for a tertiary and even a quaternary bow, but in consequence of their position between the observer and the sun, the increased faintness of their hues, and the brightness of the solar beams, they are invisible. Besides these ordinary rainbows, we sometimes meet with *supernumerary* or *supplementary arcs,* depending upon the peculiarities in the atmosphere favourable for their development.

245. The solar rays falling upon the rain-drops, suffer refraction as each individual pencil strikes obliquely the minute globule; they are then bent to a point on the posterior surface, where they suffer reflexion; and emerging, are again refracted, reaching the eye divided into their component parts, affording to the observer one of the most glorious visions upon which his eye can rest,—

> "Much mine eye
> Delights to linger on thee."

Fig. 2.

Fig. 1.

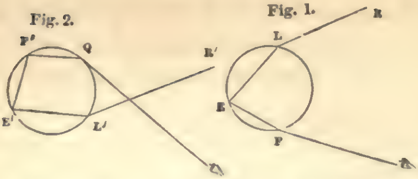


Fig. 1.—R represents the beam of light falling on the rain-drop at L, where it is refracted to E, then reflected to F, and, being again refracted on emerging, reaches the eye, forming a pencil of the primary rainbow.

Fig. 2.—R′ represents the ray of light falling on the rain-drop at L′, where it is refracted to E′, reflected to F′, again reflected to Q, and, suffering another refraction, reaches the eye, forming a pencil of the secondary rainbow.

One is awed and terror-stricken in the tempest and the thunder-storm,—he feels his insignificance in the warrings of the elements and trembles for his safety,—numbers fail to produce strength,—but now that the rainbow spans the earth, his mind is calmed,—he contemplates its peerless loveliness, and he remembers the words of Scripture,[1] "I do set my bow in the clouds, and it shall be for a token of a covenant between me and the earth. And the bow shall be in the clouds ; and I will look upon it, that I may remember the everlasting covenant between God and every living creature."

> "As fresh in yon horizon dark
>   As young thy beauties seem,
> As when the eagle from the ark
>   First sported in thy beam,—
> For, faithful to its sacred page
>   Heaven still rebuilds thy span,
> Nor lets the type grow pale with age
>   That first spoke peace to man!"
>
> CAMPBELL.

It is not our intention to inquire if this meteor had ever been beheld before the flood. It seems to us beyond doubt that it *rained* before the historic era,—the very drops have left memorials in the standstone, in the little holes with which it is occasionally pitted ; and the curiously formed eyes of certain fossils shew, that the atmosphere was then very similar to what it is now. By nations in both continents, this luminous meteor has been an object of adoration.[2]

246. Such is the explanation of the primary arc ; the secondary bow depends upon the same principles, but the rays

[1] Vide Homer,—Il. xi. 27. [2] L'Abbé Lambert, xiii. ; Burder,—Orient. Cast.

suffer *two* reflexions,—the colours are inverted. To Des Cartes[1] is due the praise of discovering the true theory of the secondary rainbow: would that with equal justice we could assign to this philosopher all that he has claimed!

247. The dimensions of the various arcs are the following:—

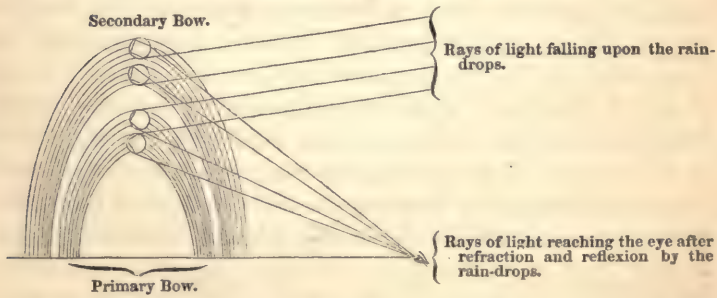
VISIBLE RAINBOWS.

PRIMARY BOW,.......	Radius of the red edge	= 42° 2′
	Radius of the violet edge	= 40° 17′
	Mean radius	= 41° 9′ 30″
	Mean diameter	= 82° 19′
	Breadth	= 1° 45′
Position,.......	Opposite the sun, the observer looking from that luminary.	
Formation,...	By two refractions and one reflexion.	
SECONDARY BOW,....	Radius of violet edge	= 54° 7′
	Radius of red edge	= 50° 27′
	Mean radius	= 52° 32′
	Mean diameter	= 105° 4′
	Breadth	= 3° 10′
	Distance from primary bow	= 8° 55′
Position,.......	Similar to that of the primary arc.	
Formation,...	By two refractions and two reflexions.	

INVISIBLE RAINBOWS.

TERTIARY BOW,......	Mean diameter	= 80° 40′
Position,.......	Encircling the sun, the observer looking towards that luminary.	
Formation,...	By two refractions and three reflexions.	
QUATERNARY BOWS,...	Mean diameter	= 91° 6′
Position,.......	Similar to the tertiary arc.	
Formation,...	By two refractions and four reflexions.	

DIAGRAM OF THE VISIBLE RAINBOWS.



248. *Supernumerary rainbows,—secundaerebogen.* Upon the violet side of the primary rainbow a partial repetition of the colours is sometimes visible, but not extending to the

[1] Traité des Meteores.

horizon. These consist of red and green, more or less distinctly marked, occupying spaces of various breadths. They have been witnessed by Mariotte, Dicquemarre,—who observed them *outside* the secondary bow; by Langwith,[1] Bouguer in Peru, Gentil in France, Bülfinger, Monge, Daval, by the author, and others. Sir David Brewster saw four on the 29th of July 1813, in the following order,—beginning with the red which was in contact with the violet,—red, green, red, green, red, green, red, green, red. Professor Twining, in September 1823, saw three, of a violet colour, unaccompanied by green, at Montreal. On the 18th of May 1826, at 6 P.M., three were seen, at Lengsfeldst, in Eisenach, in the following succession:—After the violet of the primary bow, came purple, orange, green, violet; purple, orange, green, violet; purple, orange, green.[2] These supernumerary or supplementary rainbows, M. Arago[3] explains, by the augmenting volume of the falling drops, and the interference of the luminous beams; and Professor Airy has recently solved the problem, which accounts for them upon this diffracting power of light.

249. Should circumstances be favourable, such as the presence of a sheet of water, whose surface reflects the sun's rays upon the cloud, then we shall have formed other rainbows, arising in the same manner as the primary and secondary arcs, the reflected beams being the exciting cause. These will intersect, in a point depending upon the sun's altitude, those produced directly. This phenomenon has been described as seen at Chartres, on August 10. 1665, and from the walls of Chester by Dr Halley, August 6. 1698.

250. It has been experimentally proved by Sir David Brewster,[4] that the rainbow consists wholly of polarized light, in consequence of the rays having been reflected nearly at the angle of polarization, from the posterior surface of the raindrop.[5] The value of this observation is great. In the language

[1] Phil. Trans. 1723.
[2] Karsten Archiv.
[3] Annuaire pour 1836, p. 300.
[4] Ed. Jour. of Sc. vol. x. p. 163.
[5] The polarization takes place in a plane passing through the centre of the bow and part of the arc examined. The polarizing angle for one reflection, at the 2d surface of water, is 36° 51′, and that at which the mean rays are reflected from the posterior surface of the rain-drop, is 39° 47′,—difference, 2° 56′; the polarizing angle for two reflexions from water, is 40° 1′.

of the Baconian philosophy, it is an *instantia crucis*, demonstrating the correctness of Newton's theory of the rainbow which we have explained. When the spectrum is formed from a very slender pencil of light, the yellow and the blue colours almost wholly disappear; and when obtained from one, the breadth of which exceeds the angle of separation of the red and violet, the green becomes invisible, and there is the semblance of two primary arcs separated by one of white or homogeneous light. Hence when the sun's apparent diameter is least, as in summer, there is greatest condensation of the colours, whereas in winter, the yellow and the blue predominate This leads us to mention the phenomenon of *white rainbows*, which is by no means common. It is referred to by Howard,[1] and Forster,[2] and explained by Young.[3] Coldstream[4] mentions two which were seen at Leith in 1825, and the author witnessed one on the 17th of October 1848, about 3 P.M. in England.

251. From the circumstance that the sun's meridian altitude in summer is more than 45°, we cannot at that season observe this meteor, excepting in the morning and the evening. If the cloud does not cover the whole area which the rainbow spans, it will be partially wanting or broken in those places; and when viewed from a sufficiently elevated position, it may be seen nearly to complete the circle. The frequency and beauty of this meteor greatly depend upon physical peculiarities of the locality. As witnessed in the Pacific Ocean, among the numerous volcanic isles wherewith it is studded, let the following description suffice:—" The ground being heaved into enormous mountains, with steep and narrow dells between, the sun, both before and after he passes the meridian, is continually faced by superb eminences, on which

'The weary clouds oft labouring rest,'

and showers fall many times in a day, from divers quarters, accompanied by brilliant segments of the glorious arch, which, under certain happy circumstances, may be seen bestriding

[1] Climate of London.
[2] Researches.
[3] Introd. to Med. Lit. p. 586.
[4] Ed. Jour. of Sc. vol. vii. p. 85.

the island itself from sea to sea, or resting, one foot upon the sea and the other on the earth, like the angel in the Apocalypse, who was himself 'clothed with a cloud, and had a rainbow over his head.'"[1] Although the meteor which we have attempted to describe, is explained by the most rigid mathematics, we venture to say, that to the man of science, its contemplation is productive of greater real enjoyment than ever was experienced by the uninstructed, heightened perchance by the charms of lively fancy.

> "Nor ever yet
> The melting rainbow's vernal tinctur'd hues
> To me have shone so pleasing, as when first
> The hand of science pointed out the path
> In which the sunbeams gleaming from the west
> Fall on the watery cloud."
>
> AKENSIDE,—*Pleas. of Imagination.*

252. *Lunar rainbows* do not differ in the theory of their formation from those described, but they are less bright, of a whitish colour, and occur seldom. The author observed one of great beauty, at Edinburgh, in October 1841. He was crossing the Dean Bridge about 8 P.M.,—the moon was shining with a watery whiteness, and fleecy clouds were traversing her disc. The rainbow seemed to rest upon the Lomond hills in Fifeshire, and continued visible for some minutes: it was full moon that month upon the 30th. Five other instances have been communicated by eye-witnesses:—one occurred in 1830, at Newcastle-on-Tyne; one in Cheshire in 1842; the third about two miles from Bangor, in Caernarvon, which was observed from an eminence, and rendered peculiarly grand by the romantic scenery around; the fourth was witnessed at Larbert, about the middle of November 1847, at 5 P.M.; and the fifth was seen by the Rev. Messrs Aldis and Travers, near to Nantwich, on the 6th November 1848, at 9 P.M., nearly five days before full moon. About the same time one was seen at Scarborough.

253. Aristotle, who was the first to describe the lunar rainbow, twice witnessed the phenomenon. Snellius and Plot[2] mention having been eye-witnesses of this meteor. Weilder

[1] Tyerm. and Ben.—Jour. vol. i. p. 440.

[2] Nat. Hist. of Oxfordshire.

observed one in 1719, during the first lunar quarter. In the Philosophical Transactions, several are recorded,—*e. g.* one which was seen about Christmas 1710, at Glapwell, near to Chesterfield, and described by Thoresby;[1] another at full moon, on Feb. 27. 1782, at Greta Bridge in Yorkshire, the orange colour of which predominated; a second at the same place, on the 30th July in the same year, six days after full moon; and a third, also at the same place, on the 18th of October the same year, three days before full moon,—this was of unprecedented duration, having been seen with variable brilliancy from 9 P.M. till 2 A.M.; they are described by Tunstall. One is recorded[2] to have been seen on the 17th of August 1788, at 9 P.M., twenty-three hours after full moon, from Stoke Newington; its colour was milky, with a faint green towards its western limb. A lunar rainbow was seen on the 14th December 1817, about 10 P.M., near London.[3] Dr W. Burney[4] records one seen at Gosport, on the 25th August of the same year, at 8.5 P.M., which continued about ten minutes,—the moon was nearly full; and another on the 16th September 1818, at the same place, and about the same hour.[5] One was seen at Newton Stewart, on the 17th October 1819, which continued visible about twenty minutes.[6] Tyerman and Bennet[7] saw one at sea, on the 11th September 1821, which was attended by a secondary bow,—"the colours were more obvious in this lunar rainbow than in several seen before, yet they were faint in comparison with the feeblest solar bow." This meteor was seen at Middleton, near Edinburgh, on the 1st October 1824, about 10 P.M.;[8] a second was observed on the 2d of November, at sea, before a hurricane;[9] and a third, on the 9th of the same month, at Leith.[10] One was seen on September 14. 1829, about 9 P.M., at Sturminster, in the south of England,—its altitude was nearly 40°, and its colour milky white; one in September 1838, by Armstrong; one at Edinburgh, Aug. 20. 1839, between 7 and 8 P.M.; one on October

[1] Phil. Tr. No. 331, p. 320.
[2] Gent. Mag. 1788.
[3] Ann. of Philos. vol. xi. p. 160.
[4] Ann. of Philos. vol. xi. p. 168.
[5] Ib. vol. xii. p. 368.
[6] Ib. vol. xiv. p. 472.
[7] Jour. of Voy. & Trav. v. i. p. 48.
[8] Edin. Even. Courant.
[9] Ed. Jour. of Sc. vol. iii. p. 57.
[10] Ib.

18. 1842, from a mountain in South Wales, at full moon,—it remained visible above ten minutes, and from the altitude of the observer, more than a semicircle was beheld.

254. Marine rainbows[1] are not unfrequently seen upon the waves, vivid and distinct, but evanescent, the convex side turned to the sea; the meteor is visible also in mists,[2] and upon the grass in the morning dew,[3] the curved part being next the eye. Rainbows may be artificially produced, and some of the finest, are those visible in cataracts and cascades, when the sun shines upon the water. This beautiful phenomenon may be observed on the Corra-Lynn, near Lanark; the Fall of Foyers, and upon the spray of several other waterfalls in Scotland. The Falls of Niagara and the Missouri; the cataracts of Maypure on the Oroonoko, and the Rio de Bogota at Tequendama in Colombia, exhibit the same lovely spectacle. To this an illustrious poet refers, when describing the torrent of Velino,—

> "A matchless cataract,
> Horribly beautiful! but on the verge,
> From side to side, beneath the glittering morn,
> An Iris sits amidst the infernal surge,
> Like Hope upon a death-bed, and, unworn
> Its steady dyes, while all around is torn
> By the distracted waters, bears serene
> Its brilliant hues with all their beams unshorn."
> *Childe Harold*, canto iv. lxxii.

Pliny,[4] remarking upon the Velinus lake, notices the rainbow, —"in eodem lacu, nullo non die apparere arcus." The falls of the Rhine near Schaffhausen; the cascade of Sallenche near Martigny; the noble waterfall of the Aar above Guttanen, near the Grimsel; and the Alpbach near Meyringen, might be mentioned,—the last presents a *triple* iris, the inner bow being nearly a full circle and the others more or less so, according to the volume of rushing waters. The lofty Staubbach, not far from Lauterbrunnen,—the "heaven-born waterfall" of Wordsworth,—presents at noon a glorious iris on its "water-dust;"—

[1] Bourzes,—Phil. Tr. No. 337, p. 235; Tyerm. & Ben.,—op. cit. vol. i. p. 22, &c.
[2] Mariotte,—Essai de Physique. [3] Rohault,—Tr. de Phys.
[4] Nat. Hist. ii. 62.

"It is not noon,—the sunbow's rays still arch
The torrent with the many hues of heaven,
And roll the sheeted silver's waving column
O'er the crag's headlong perpendicular,
And fling its lines of foaming light along,
And to and fro, like the pale courser's tail,
The giant-steed, to be bestrode by Death,
As told in the Apocalypse."

Manfred, act ii. sc. ii.

255. The *Corona* is a meteor appearing in certain states of the atmosphere, encircling the heavenly bodies, but chiefly the moon, and generally the precursor of a change of weather. In Scotland, it is termed a *brough* when of large dimensions. It appears like a large, generally whitish, nebulous patch, in the centre of which is the heavenly body: the *halo*, on the other hand, is a prismatic ring of variable diameter, and sometimes concentric with other circles; the halo properly so called, is of considerable radius. Coronæ and halos are visible only in a moist or cloudy atmosphere, or through mountain mists. In coronæ, the blue prismatic colour is nearer the centre than the red; in halos, this arrangement is reversed. Coronæ appear in cumuli, halos in cirri clouds; the former arise from diffraction, the latter from refraction, of light.[1]

256. Humboldt mentions having seen, when near the equator, small halos around the planet Venus, but never surrounding the fixed stars. The Baron witnessed an unusually beautiful lunar halo at Cumana, consisting of a double circle, the larger being 44° in diameter, and the other only 2°; the former was of a whitish colour, the latter was prismatic, and the intermediate space was deep azure; the air was perfectly transparent, but the hygrometer indicated intense humidity. Sir John Franklin,[2] in the arctic regions, witnessed prismatic coronæ surrounding the flames of candles in the apartments.

257. These meteors may be observed, not unfrequently, around the sun, but the brilliancy of the solar rays prevents their being directly visible; however, by receiving the sun's image in a pool, or on a darkened mirror, they may be de-

[1] Kämtz,—Lehrb. der Met.

[2] Nar. 3d Ed. v. ii. p. 31.

tected. Sir Isaac Newton[1] observed three concentric heliacal rings in June 1692. The colours of that one nearest the sun, were blue, white, and red; those of the intermediate ring, were purple, blue, green, pale yellow, and red; that one external to the others was coloured pale blue within, and pale red without. The diameter of the first circle was about 5°, and that of the second 12°. Huygens[2] describes a solar halo which he noticed on the 13th of May 1652. "I observed," says he, "a circle about the sun as its centre; its diameter was about 46°, and its breadth the same as that of a common rainbow. It had also the same colours, though very weak and scarcely discernible, but in a contrary order, the red being next the sun, and the blue being very dilute and whitish. All the space within the circle was possessed by a vapour duller than the rest of the air, of such a texture as to obscure the sky with a sort of continued cloud, but so thin that the colour of the blue sky appeared through it. The wind blew very gently from the north." Dr Burney[3] records several solar halos in the year 1817, one of which, seen on the 5th of June, from 7 till 9.5 A.M., was particularly fine; its diameter was 44°: a light yellow corona was at the same time concentric with the sun, and between this circle and the interior edge of the halo, the atmosphere seemed to be darker than that outside the meteor. At St Petersburgh, seven occurred in 1818, and nine in the following year:[4] in this country, forty-two and thirty-two are recorded during these years respectively,[5] showing that the phenomenon is at times by no means rare.

Armstrong of South Lambeth describes a solar halo which he witnessed near London on the 14th of July 1831, at 6.5 P.M. The sun was then about 10° above the horizon, and his disc was encircled by this meteor, which displayed the prismatic colours of the spectrum. The radius of the halo was, as nearly as the eye could determine, ten degrees; it lasted two hours, disappearing as the sun went down. The same ob-

[1] Optics, book ii. part iv. obs. 13.
[2] Op. Posth. p. 366.
[3] Annals of Philos. vol. xi. p. 167.
[4] Longmire, ib. vol. xx. p. 17.
[5] Burney, ib. vol. xv. p. 430.

server mentions another, seen on the 20th of April 1840. The author witnessed a partial solar halo on the evening of May 23. 1847, at Wrenbury, near to Nantwich. The day had been fine and exceedingly warm, but towards sunset a change was foreboded. Cirri floated in the zenith, and the sun's disc was hid in a cirro-stratus cloud, but a bright watery light showed that that luminary was still a few degrees above the horizon. From the centre of this light there radiated, not beams, but clouds; it was through one of these, and nearly 20° from the sun, that the halo appeared; the colours were remarkably vivid, the red being internal. The barometer fell two-tenths of an inch, and there was a high wind with slight rain the following day. On the 1st of September 1848, at the same place, he observed another of these meteors, more beautiful than the last.

At Boston, on June 16. 1843, at 2.5 P.M., a solar halo with prismatic colours on the N. E. and S. W. was seen. Surrounding this was a much larger circle, whose centre was nearly in the zenith, and having the sun in the S. W. of its circumference. It was of a pale white hue, and well defined; the interior of this halo, excepting the sun's disc, was much darker than the surrounding atmosphere. It will be shown hereafter, that this double halo belonged to one of the most beautiful descriptions of luminous meteors, that of the parhelion with its system of prismatic circles. A curious system of solar halos was seen by Mr Lowe[1] in Notts, on the 19th of October 1846.

258. Halos and coronæ may be artificially produced, as has been described by Otto Güericke, Muschenbroek, and Sir David Brewster. Thus, if we pour upon a piece of plate-glass a solution of alum and allow it to evaporate to dryness, the surface will be coated with octahedral crystals of that mineral, whose homologous facets incline at a uniform angle. Interposing this between the eye and a luminous point, artificial halos are produced. The circle nearest the centre, is formed by the refraction of the light by those facets which have the smallest inclination, and this halo is the whitest because the ray has been least dispersed; the next concentric

[1] Phil. Mag. 1846, vol. xxix. p. 440.

halo is red within and blue externally, and formed like the last, only, the angle of refraction has been more inclined and the dispersion thereby increased; the third, is still larger, and is of a similar origin, but from a larger incident angle and still greater dispersion. These crystals covering the glass, a spectrum is formed with every similar pair of refracting planes, and thus the figure is circular.

259. The curious phenomena of *Glories,—anthelia,*—or coloured circles surrounding the shadows of the observers, have been frequently noticed. Occasionally they are accompanied by a white circle of vast diameter. M. Bouguer[1] mentions that when he, Don Antonia Ulloa, and his companions, were upon the summit of Mount Pickincha, one of the Cordilleras, and the sun just rising behind them, each saw his *own* shadow distinctly projected with a glory surrounding the head. The anthelia consisted of three concentric circles of a lively colour and prismatic, the red being external. The intervals between them continued equal though their magnitude varied. Surrounding all, was a great white circle whose diameter was 67°. This phenomenon, he observes, appeared in a cloud consisting of frozen particles, but never in rain-drops like a solar iris. Hevelius, in 1661, witnessed this meteor at Dantzic. One was seen on the 18th of January 1738, at Wittemberg. In 1762, the phenomenon was observed by Swinton near to Oxford; it attracted the notice of Howard at Folkstone; and is described from personal observation by Haygarth.[2] During the intense frost of January 1820, this beautiful meteor was seen at Perth, upon the fog which arose from evaporation from the ice upon the Tay.[3] Looking from the bridge, the spectator beheld his shadow on the vapour, of gigantic size, surrounded by a halo and throwing off prismatic radiations. Ramond[4] saw this interesting meteor among the Pyrenees, when the temperature was believed to be too high for the presence of gelid particles. Another remarkable example occurred to a gentleman upon an eminence in Scotland, while a dense mist was hovering

[1] Hist. de l'Acad. des Sc. 1744.
[2] Manch. Mem. vol. iii.
[3] Ed. Phil. Jour. vol. ii. p. 335.
[4] Ed. Jour. of Sc. v. v. 180.

over the land, obscuring every thing but the summits of the surrounding hills. He saw his shadow cast upon the mist, and round it was an arc of prismatic hues; at another time he observed a double ring surrounding, and distant about two feet from his shadow. Mr L. Agassiz[1] witnessed the phenomenon from the Rigi-calm in Schwyz, at sunset. A large prismatic arc, about 4–5ths of a circle, attracted his attention, in the centre of which there appeared "a small but perfect circle of faint colours, ring within ring like a target, within which we saw our own contours as clearly delineated as in a looking-glass." In 1841, a party witnessed the same phenomenon from the Faulhorn. Scoresby[2] witnessed this meteor in the polar regions, when sunshine and a fog coexisted. On the 23d of July 1821, four concentric circles appeared to him, of the following radii and colours:—α, nearest his head; radius, $1° 45'$; *hues*, white, yellow, red, purple,—all very vivid: β, next to α; radius $= 4° 45'$; *hues*, blue, green, yellow, red, and purple,—all very vivid: γ, radius $= 6° 30'$; *hues*, green, whitish, yellowish, red, and purple,—indistinct and sometimes invisible: δ, radius $= 38° 50$; *hues*, faint green and white. Kämtz[3] twice witnessed a similar appearance on the Alps, the mean radius of the largest circle being $39° 48'$; Bravais at Bell Sound, Spitzbergen, measured one the radius of which was $45°$; and from five observations, in 1841, on the Faulhorn, he derived a mean radius of $38° 54'$. The mean radius obtained from all these records equals $39° 12'$, while that of the primary rainbow is $41° 9' 30''$, consequently these phenomena are distinct and cannot be accounted the same.

260. An appearance analogous to this meteor is mentioned by Mr Green as having been sometimes seen by him from his balloon, at altitudes of about two miles. It is a shadow of the balloon beautifully depicted on the upper surface of a cloud, invariably encircled by a triple iris. A similar effect was witnessed by Prince Pückler Muskau, a Silesian nobleman,—the "German Prince," author of the *Tour*,—upon an ascent with Mr Richard from Berlin. The balloon and its

[1] Jour. to Switzerland. [2] Journ. pp. 274–284.
[3] Kämtz et Mart. Met.

æronauts appeared upon the clouds of colossal magnitude, surrounded by many prismatic wreathes.

261. The immediate cause of the prismatic colours of the meteors described, is the diffraction[1] or inflexion[2] of light, dependent upon the undulatory theory of that fluid; or the different refrangibility of the solar rays suffering refraction in passing through media of unequal density. The size of the vesicles of the interposed vapour, and the diameter of the meteor, are in direct ratio; when the vesicles are of equal magnitudes, the phenomenon is perfect, but should they vary in size, it undergoes modifications according to the peculiarities of the case. Mariotte[3] long since referred the halo to the refraction of light by prismatic crystals of snow floating in the higher regions of the atmosphere,—an opinion supported by observations made by Arago[4] on the 11th of April 1825, with an instrument invented by him for the examination of polarized light. When the phenomenon arises from the interposition of cirri, this is doubtless the case, for the altitude of these clouds is within the regions of perpetual congelation. This theory is supported by Young, Cavendish, and others. The hypotheses of Des Cartes, Huygens, and Newton, being accounted untenable, we need not dwell upon them.[5]

262. The *Parhelion,* or Mock-sun,—*Nebensonne,*—frequently seen in the polar circle, is one of the finest of the luminous meteors of our atmosphere. It presents the appearance of halos and luminous arcs, intersecting with mathematical precision, and studded with solar images. In the following descriptions of the phenomenon, it will be observed that there is a remarkable regularity preserved, although occasionally some parts may be wanting. The circles which most frequently appear are those which surround the true sun, and

[1] Grimaldi,—Physico-Mathesis de Lumine, Coloribus et Iride. Bononiæ 1665, —Ph. Tr. 1672, No. 79. p. 3069; Fraunhofer.

[2] Newton,—Optics.

[3] Œuvres, i. 272; Tr. des Couleurs, Par. 1686.

[4] Bullet. Univ. Mai 1825.

[5] Vide Des Cartes,—Meteorol. x.; Huygens,—Dissert. de Cornuis et Parhel.; Newton,—Opt. book ii. pt. iv. obs. 13; Priestley,—On Vision, &c. vol. ii.; Dr T. Young,—Nat. Phil.; Wood,—Manch. Mem. vol. iii. 336; Smith,—Optics, vol. i.

that one which passes through his disc parallel with the horizon. Besides these, tangental arcs are often visible. Occasionally, segments of vertical circles render the meteor more complicated. The *Paraselene* is a similar phenomenon occurring at night, when the moon is shining. Arago[1] has observed that the circumstances favourable to these phenomena may exist over a wide extent; thus, parhelia were visible on the 13th of May 1838, in the Departments of Aisne and Nord; and upon the 29th of March 1848, in the south of England and Guernsey.

263. Aristotle records two appearances of this meteor; and Pliny mentions their occurrence at Rome. A double parhelion, which was noticed before the Christian era, is referred to by Augustine; and Zonaras mentions two seen after the death of Christ. In England the phenomenon is said to have been witnessed in the year 346, when, besides the true sun, four mock-suns were visible; two in 812, and the same number in 953. Holinshed records one in 1199 on the authority of William Paruus, an eye-witness, and he quaintly observes, —"At length when the beholders had well wearied their eyes in diligent marking the manner of this strange appearance, the counterfeit sunne vanished awaie."[2] Matthew Paris, monk of St Albans and historian,[3] mentions a meteor of this kind which was seen from sunrise till noon on the 8th of April 1233, in the 17th year of the reign of Henry III. Four mock-suns were visible in a white circle which passed through the sun, equidistant from each other and having the true luminary between two of them; where the parhelia appeared, arcs, the vertices of which turned to the centre of the large circle, cut that ring. On the 1st December 1236, the phenomenon is again recorded.[4] Palmerius mentions three suns seen in 1466. In the year 1514, three were witnessed at Wirtemberg, on the authority of Surius; and in 1532, the same number at Venice, on that of Cardan. In 1551,—a year remarkable for earthquakes and meteors, and no less memo-

[1] Compt. Rend. tom. vi. p. 373–501.
[2] Chron. vol. iii. p. 157.
[3] Hist. Mag., Rer. Anglic. Historia, a Gul. Conq. adventu ad an. 43 Hen. III,—Chron. of Roger de Wendover of same convent; Hol.—Chron. vol. iii. p. 216; Ed. Encyc. Art. Halo, vol. x.
[4] Hol. vol. iii. p. 220.

rable for the 5th visitation of the sweating sickness,[1]—several parhelia were visible. Thus, on the 28th February, mock-suns were seen at Antwerp;[2] on the 17th of March a similar phenomenon, with two halos, was witnessed;[3] and on the 21st, at 7 A.M., two parhelia with three halos were seen at Magdeburgh, and in the evening two paraselenæ;[4] at Wittemberg the mock-suns were observed, but not the other meteors. On January 2. 1586, Christopher Rotham saw at Cassel, before sunrise, an upright column of light of the breadth of the sun's disc. He rose, preceded and followed by a parhelion, which appeared in contact with his orb; they continued visible for thirty minutes, till obscured in a cloud. In 1596, Barentz, at Nova Zembla, saw the sun attended by two parhelia and three halos. In 1619, three were visible, on the authority of Fromundus. Scheiner witnessed a singular one at Rome on the 20th of March 1629: from the zenith as a centre there was seen a great white circle, having the true sun in its circumference; this was intersected by two concentric circles around his disc; where the outer of these smaller rings cut the zenithal circle two parhelia appeared, and in the great circle, nearly opposite to these, but separated by a wider arc, two others were visible. Gassendi[5] describes a very

Parhelia seen in 1233, in England.

Parhelia seen by Scheiner in 1630.

remarkable phenomenon of this kind, which was seen in 1630 by Scheiner. Around the sun were two concentric halos, the

[1] Hecker,—Epidem. Mid. Ages.

[2] Chronici Chronicorum, 1614, p. 402.

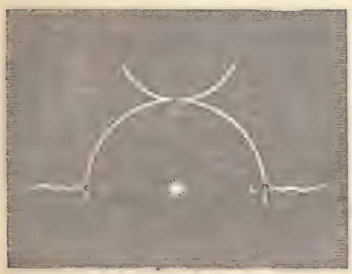
[3] Spangenberg.

[4] Ch. Chron. p. 401; Angelus—Annales Brandenburg. 1598. p. 344; Mansfeldische Chronica,—Spang. fol. 464; Hecker,—Epidem. p. 296.

[5] Opera, tom. vi. 401.

larger cut the horizon and consequently was incomplete; these were coloured like the rainbow, excepting that the red was internal. In the direction of the zenith, there was a tangental arc external to these halos; and with the zenith as a centre, a great white circle ran parallel with the horizon, having the true sun in its circumference. At the five intersections of these circles and arcs parhelia appeared, and a sixth was seen in the internal halo between the true sun and the zenith. Gassendi was an eye-witness of the phenomenon in 1635 and 1636. Lilly mentions two mock-suns seen on the 19th of November 1644; and two appeared on February 28. 1648. At Leyden, on January 14. 1653, between the hours of 1 and 2 P.M., Kechelius saw from the Observatory two parhelia, distant about 22° 35′ from the sun, which was the centre of the circle in which they appeared; the western was the fainter, and disappeared first; from the eastern, a tail issued 27° in length. On the 6th of April 1660, at 5.5 P.M., when the sun was nearly set, Hevelius noticed a partial circle about 22°.5 from his centre, tipped above by a tangental arc. Opposite the sun, north and south, in the circumference of the halo, two parhelia with tails were visible, and a third appeared in the intersection of the arcs. In 1666, six suns were seen at once at Arles.[1]

264. One of the finest meteors of this kind on record was seen by Hevelius[2] at Sedan on the 20th of February 1661.



Parhelia seen in 1660 by Hevelius.

Parhelia observed by Hevelius at Dantzic, Feb. 20. 1661.

"A little before 11 o'clock," he says, "the sun being towards the south, and the sky very clear, there appeared seven suns

[1] Coetlogon,—Univ. Hist. of Arts and Sc. vol. ii. p. 429.

[2] Mercurius in Sole Visus, p. 174.

together, in several circles, some white and others coloured, and these with very long tails waving and pointing from the true sun, together with certain white arches crossing one another. The true sun was about 25° high, and surrounded almost entirely by a circle whose diameter was 45°, and coloured like a rainbow with purple, red, and yellow, its under limb being scarcely $2\frac{1}{2}$° above the horizon. On each side of the sun, towards the W. and E., there appeared two mock-suns, coloured, especially towards the sun, with very long and splendid tails of a whitish colour terminating in a point. A far greater circle, almost 90° in diameter, encompassed the sun and the former lesser circle, and extended itself down to the horizon. It was very strongly coloured in its upper part, but was somewhat duller and fainter on each side. At the tops of these two circles were two inverted arcs, whose common centre lay in the zenith, and these were very bright and beautifully coloured. The diameter of the lower arc was 90°, and that of the upper one was 45°. In the middle of the lower arch, where it coincided with the circle, there appeared another mock-sun, but its light and colours were dull and faintish. There appeared a circle much bigger than the former, of an uniform whitish colour, parallel to the horizon at the distance of 25°, and 130° in diameter, which arose as it were from the collateral mock-suns and passed through three other parhelia, of an uniform whitish colour like silver; one parhelion almost 90° from the sun, towards the east; another towards the west, and a third in the north, diametrically opposite to the true sun, all of the same colour and brightness. There passed also two other white arches of the greatest circle of the sphere through the eastern and western parhelia, and also through the pole of the ecliptic. They went down to the horizon, crossing the great white circle and obliquely, so as to make a white cross at each parhelion; so that seven suns appeared very plain at the same time." This phenomenon, with certain changes in the brightness of its several parts, continued visible eighty minutes.

M. de la Hire, in 1689; Cassini, in 1693; Grey, in 1700; and Halley,[1] in 1702, were eye-witnesses of this meteor. Upon

[1] Phil. Tr. 1702, vol. xxiii. p. 1127.

the 2d of January 1712, four were seen at Boston, New England, and the same number about six weeks thereafter.[1] Weilder,[2] in 1736, witnessed the phenomenon; and Musschenbröck, at Utrecht, mentions having seen four mock-suns at once. In December 1741, three suns were visible from 9 A.M. till noon, at Canterbury,—the preceding day a luminous meteor crossed the city, about twelve o'clock, followed by a storm which broke "almost all the windows in the town."[3] In 1762, one was seen by Swinton,[4] near Oxford. Barker[5] describes a curious halo with accompanying parhelia, which he saw at Fort Gloucester, near Lake Superior, on January 22. 1771: a circle with tangental arc surrounded the sun; about midway between the horizon and zenith, a circle ran parallel to the horizon, having the sun in its circumference; in this horizontal circle there appeared altogether five mock-suns, with this peculiarity, that directly opposite the true sun in this great circle a St Andrew's cross was seen, the upper limbs of which extended higher above, than the lower one descended below, this circle; in the intersection of this cross and the circle, one of the parhelia was placed. Maleziew saw two parhelia touching the sun on either side, in 1772. During an aërial voyage of M. Guyton Morveau and the Abbé Bertrand, from Dijon, on the 25th April 1784, when the sun's altitude was 10° and the balloon far above the region of the clouds, a mock-sun appeared within six degrees of the true luminary: it consisted of many delicate prismatic rings depicted on a snow-white ground. One of the most complicated systems of halos and parhelia witnessed, was observed by M. Lowitz at St Petersburgh in June 1790, between 7.5 A.M. and 12.5 P.M. Two parhelia appeared at Niort on March 25. 1798, between 6 and 8 A.M.

265. In the present century several appearances are recorded. Sir Henry Englefield[6] describes a very curious one seen at Richmond, Surrey, on the 20th of November 1802, at 2 P.M.; the parhelion above the sun was brighter than the

[1] Ib. No. 339, p. 66; Motte's Abr. v. ii. p. 112. [2] De Parhel. Ann. 1736.

[3] Cirenc. Flying Post, No. 54, Dec. 28. 1741.

[4] Phil. Trans. Abr. xi. 532. [5] Ph. Tr. 1787, vol. lxxvii. p. 44.

[6] Jour. Roy. Inst. vol. ii; Young,—Nat. Phil. v. i., pl. 29, fig. 431; Nicholson's Jour. vol. vi. p. 54; Ed. Encyc. vol. x.

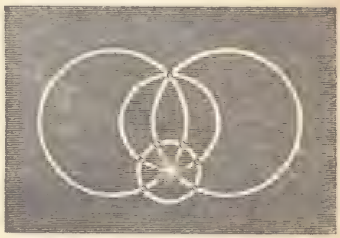
true luminary; it was nearly 2° broad, and there proceeded from it, on either side, a bright ray, which gave it the semblance of a bird with extended wings. In January 1809, six were seen at once in Greenland. Upon the 8th of September 1816, parhelia were seen at Rhode Island;[1] on the 19th of March 1817, one was seen by Howard,[2] at Tottenham; and on the 9th July 1818, two were visible at the same place,—the *halo* was seen at Hertford.[3] On the 26th of August same year, Dr W. Burney[4] beheld one at Gosport, at 6.5 A.M., and two, beautifully coloured, an hour afterwards; on the morning of the 25th September, he saw two;[5] and on that of the 26th, three coloured parhelia appeared. Upon the 2d October same year,[6] about sunrise, the same observer witnessed a mock-sun parallel with the solar disc; on the 9th, about 8 A.M., and on the 17th and 28th of the same month, there was a recurrence of the phenomenon;[7] in November, same year, he witnessed parhelia at the same place—on the 3d, 13th, and 25th. On the 29th January 1819, two were seen by Mr L. Howard;[8] and on the 25th September, two others: during the same year, a considerable number have been recorded by Burney.[9] On the 5th of April 1820, two parhelia were seen at Kilkhampton, in Cornwall, and at St Gennys, twelve miles to the south-west,—at the latter place the *halo* was invisible.[10] In the same year, two were seen at Augsburg in Germany, and Dr Burney[11] enumerates several witnessed at Gosport. On the 8th March 1823, two appeared at York, about 3 P.M.[12]

Hoff and Kries[13] have described a meteor of this kind which was witnessed at Gotha on the 12th May 1824. Opposite the true sun, portions of two vertical circles cut each other in the great horizontal circle, where a mock-sun was seen; four other images appeared in this circle, two in the circumference cut by the halo in whose centre was the true sun, and two others at angles of 90° from the true luminary.

[1] Ed. Jour. of Sc. vol. vii. p. 113. [2] Ann. of Philos. ix. 411. [3] Ib. xii. 160.
[4] Ib. xii. 235. [5] Ib. xii. 369. [6] Ib. xii. 370. [7] Ib. xiii. 444.
[8] Ib. xiii. 240, and xiv. 400. [9] Ib. xv. 429.
[10] Proceed. Cambr. Phil. Soc.; Ed. Phil. Jour. vol. iii. p. 187.
[11] Ann. of Philos. xvii. 365. [12] Ed. Phil. Jour. vol. viii. p. 395.
[13] Ed. Jour. of Sc. vol. ii. p. 105.

External to the small circle around the sun, and opposite to the parhelion first mentioned, was an arc cut by the horizon, having another image in the point of junction with the small circle. Around this circle, and concentric with it, was seen a portion of another solar circle, limited by the great circle, with its apex towards the zenith, and joined by a tangental arc; a small portion of another tangental arc tipped the small circle; and between these concentric circles was a portion of another, of larger radius, also terminated by the great circle. A very curious system of circles, with five mock-suns, appeared on Aug. 19. 1825, at Jackson, Tennessee.[1] The same

Parhelia seen at Gotha,—Hoff and Kries.



Parhelia seen Aug. 19. 1825, at Jackson, Tennessee.

year parhelia were seen at other places in America, and at Leith. Schult, Hansteen and Segelke mention one seen in Norway, on the 27th March 1826; Arago, one seen in France on the 13th of May 1838; Bravais and Martins, one at Piteo, in Sweden, on the 4th October 1839, which continued from 9 A.M. till 3 P.M.[2] One was met with on December 24. 1840. about 11 A.M. at Wisbeach.[3] A fine example occurred a few years ago, at Kiathka, in Siberia, in the month of February: the frost was intense, when at sunrise luminous rays were seen on both sides the sun's disc, and at 10 A.M these changed to brilliant parhelia. A column of light issued from the western side of his disc and a vast luminous circle—the horizontal circle—extended over the sky, in which were placed at regular distances from each other and the true sun, seven mock-suns. There were besides four large white circles dis-

[1] Ed. Jour. of Sc., vol. vii. p. 114.

[2] Meteorol. Kämtz et Martins.

[3] Athen. No. 688.

posed in a pyramidal form, of which two were circumscribed in the circle mentioned, and the others were in the horizon opposite the sun: there were four circles in the large one, one of which was effaced by the brightness of the sun's rays, and of another, only a semicircle was visible, presenting prismatic colours. This curious meteor lasted till nearly noon. A parhelion was seen at Cork in March 1843 at 4.5 A.M.;[1] and at Derby on June 16, same year; also on the 21st October 1844, when two mock-suns were visible.[2] Three parhelia were visible at Aberdeen about 7 P.M. on June 12. 1847: they were disposed at right angles, and were intersected by a pale circle of light, at the base of which was the true sun slightly brighter than the mock-suns: that at the upper part of the circle was much smaller and paler than the others. Within the circle there was a large dark cloud, the edges of which were of prismatic hues. Upon the 29th of March 1848, a system of halos and parhelia attracted general observation in the south of England and Channel Isles, between the hours of 11 A.M. and 5 P.M. Parry[3] and Fisher[4]

Parhelia seen by Parry.

Parhelia seen by Parry.

describe several seen in the arctic regions; and the latter observes,[5] that the colours were most vivid either when a little snow was falling or when fine crystals of ice were floating in the atmosphere. Maraldi, Weilder, Ellis, Lyon, and others, have made similar observations.

An exceedingly curious optical appearance belonging to this class of phenomena, was observed by Mr Fallows[6] on 7th

[1] Phil. Mag. No. 158.
[2] Ib. vol. xxvi. p. 264.
[3] Jour. of Voy. 1819–20, 4to. pp. 156, 164, 172.
[4] Arct. Jour. *passim.*
[5] Ib. p. 186.
[6] Ed. Ph. Jour. vol. x. p. 363.

May 1823, at the Cape of Good Hope, when the sun's disc was just dipping in the ocean. On either side of the true luminary, and within the breadth of a degree and a half of his disc, four mock-suns appeared on the left, and three on the right. They had the same shape as the true sun, touched the water at the same instant, and all of them disappeared together, shining as bright spots upon the water's edge. It was a delightful evening, without a cloud; the barometer was 30.2 inches and the thermometer 64° F. This most probably was an instance of lateral mirage.

266. According to Dr Thomas Young, parhelia and paraselenæ, with their accompanying luminous circles and segments, depend upon the combined reflexions of the solar or lunar rays, from the facets of snowy prisms floating in the atmosphere, a theory which, in the 17th century, was entertained by Huygens.[1] When the snowy crystals are at the same time prismatic and lamellated, the rays suffer both refraction and reflexion, and a combination of excentric circles results.

267. The first or *internal solar circle*, is produced in the same manner as the artificial halos which we have explained, through prismatic crystals of ice and snow floating in the air, giving rise to a halo whose radius is nearly 22°, having the red within, and vivid in proportion as the ray strikes the crystal at the minimum angle of deviation,—for there is a position in which the prism may be placed, so that the incident angle may be varied without producing a corresponding change in that of refraction. The second or *exterior solar circle*,—the *extraordinary halo*,—is concentric with the former, less vivid, and distant from the sun about 46.5°; the red is internal: its explanation is less easy than that of the former. According to Galle, it arises when the icy prisms are terminated in hexagonal planes at right angles to the lateral faces of the crystal, through which diedral angles, in the proper position of the crystal, the light suffers refraction. Cavendish suggested that this halo arose from refraction by the terminal right angles of the prisms. Were it, as Young and Brandes

[1] Dissert. de Corn. et Parhel.; Smith's Optics, vol. i.

suppose, the effect of refraction through two prisms, one behind the other, the radius of the circle would be nearly 44°, which it is not; consequently, we must adopt another hypothesis, and the suggestion of Cavendish, and theory of Galle, explain the phenomenon. Besides these, a *third concentric solar circle* is sometimes, but rarely, met with; it is much larger than the others, having a radius of 90°, and the red external. In this case the ray of light suffers refraction, after reflexion by the posterior surface of the hexangular prism.

268. The *tangental* or *circumzenithal arcs* arise from refractions through horizontal prisms. Galle[1] explains that of the second or extraordinary halo,—the *circumzenithal external arc*,—by refraction through prisms the axes of which are vertical to the horizon, the light impinging upon one of the facets and emerging by the hexagonal termination below.

269. The white-coloured *parhelic circle* which passes through the sun and runs parallel with the horizon, is, according to Dr Thomas Young, derived from the reflexion of the vertical prismatic facets of the crystals which are floating at all azimuthal distances. Fraunhofer and Schmidt consider it the consequence of diffraction.

270. The *parhelia* result, according to Young, from two refractions and an intermediate reflexion within the same prism. They are rarely met with opposite the sun in the great horizontal circle, but frequently at the intersections of this and the other circles, and the meetings of the latter halos with the tangental arcs,—not exactly *in*, but a little beyond the circle, and distant from the sun in proportion to the altitude of that luminary. According to Bravais, the amplitude of this lateral deviation is inappreciable when the sun's altitude is zero, but it amounts to 18′ at that of 10°, to 1° 13′ at that of 20°, to 3° 2′ at that of 30°, and to 5° 46′ at that of 40°.

271. Paraselenæ are frequently met with, but less often than parhelia. Five moons were seen at once, in Yorkshire, at the commencement of a severe winter in the year 1200:[2] two appeared in the winter of 1215. Hevelius observed this

[1] Poggend. Annalen. xlix. 261.

[2] Hol. vol. iii. p. 163.

meteor at Dantzic, on the 30th March 1660; it lasted nearly three hours. Around the moon were two concentric circles with tangental arcs; the paraselenæ appeared in the inner halo, to the east and west of the true moon, and from them issued tails which extended as far as the external circle.

Paraselenæ seen at Dantzic, by Hevelius, Mar. 30. 1660.

Paraselenæ seen by Hevelius, Dec. 17. 1660.

Again, on the 17th December, in the same year, he saw a similar phenomenon, which continued from 6.5 A.M. till sunrise. About 22°. 5 from the moon there was a prismatic circle, cut by the horizon and tipped by a tangental arc; opposite the moon, north and south, two paraselenæ appeared with luminous tails, and at the intersection of the arcs a third image was visible. In addition, a white and bright cross with the moon in its centre, pointed three of its limbs to the mock-moons and the fourth to the horizon; in the angles close to the moon, there was a corona, upon which the cross seemed to be projected. Muschenbröck has recorded a fine example. On the 12th of April 1816, at 9 P.M., two paraselenæ were seen from the Observatory at Prague, by David; the meteor lasted about an hour. Forster records one seen on the 30th July 1817, at 11.5 P.M. Two are mentioned by Burney[1] as witnessed in November 1818; seven in 1819; and ten in 1820. Several are recorded by Fisher,[2] seen in the arctic circle. On the 1st January 1820, at 11 A.M., he observed a halo 45° in diameter, intersected by two luminous columns of a yellowish-white colour, which crossed the moon at right angles and were equal in breadth to her disc; these columns, as they approached the halo, tapered to a point, and

[1] Ann. of Philos. xvii. 365.

[2] Journal *passim*.

in their meetings with the prismatic circle, mock-moons were visible, the two horizontal ones having a long tail extending beyond the halo. Dr Traill[1] observed a paraselene, at Liverpool, on the 30th of March in the same year, about 10 P.M. On the 25th October 1825, two circles were observed at Kensington, about 10.5 P.M., the one circumzenithal and the other around the moon, but no image of our satellite was seen at their intersections[2]. Several paraselenæ were seen in 1827 in Bedford.[3] A similar meteor was witnessed by Mr Birt[4] on May 6. 1841 ; on September 25. same year, two paraselenæ were visible ; on May 1. and October 20. 1844, similar meteors were seen by Mr Lowe.[5] A fine meteor of the same kind was seen by Professor Page[6] on the night of April 19. 1845. On the first of June 1847, between the hours of 11 and 2, a luminous circle surrounded our satellite,[7] on which were two paraselenæ, one on each side of the moon. A partial appearance of this meteor was witnessed by Dr Armstrong of South Lambeth, on the night of the 25th February 1842. The moon was that day full and rose about 7 P.M. When at an altitude of nearly 10°, a bright belt crossed her disc, of the same apparent diameter, perpendicular to the horizon, uniformly well defined, and terminating at each end in a small cirri-stratus cloud ; at 8 o'clock it shortened at the upper extremity. Its edges underwent no diminution in brightness, but inclined 45° to the moon's horizontal diameter, preserving this position till the phenomenon had entirely vanished.

272. Cassini, Lattire, Feuillée, and others, mention having seen the sun rise and set with a perpendicular column of light, projecting sometimes upwards, at other times downwards, to the distance of 6°, and the breadth of his disc. Mr Ellis at Churchill, Hudson's Bay, observed the sunrise heralded by two long columns of red light about 20° distant on either side. Just as his disc had risen, these luminous beams converged forming an arc, with a kind of parhelion over the true

[1] Ed. Phil. Jour. vol. iii. p. 402. [2] Ann. Phil. xxviii. 236.
[3] Unit. Ser. Jour. 1829, i. 357. [4] Phil. Mag. No. 121. [5] Ib. vols. 25 and 26.
[6] Silliman's Amer. Jour. 1846, N. S. vol. i. p. 136. [7] Poole Herald.

sun. These streams of light, he says, are connected with two other parhelia which rise with the sun, and in the winter season accompany him during the day, disappearing with him in the evening. A phenomenon of this kind was seen at Toula in Russia,[1] in July 1819. Captain Lyon[2] describes a singularly beautiful appearance, which he saw in the arctic regions, on Nov. 20. 1821. Previous to sunrise a spiral ray of delicate pink shot from the horizon, and increasing in size and brilliancy, reached the zenith, at which time its form was that of a blowpipe flame. On the appearance of the sun, the whole eastern sky partook of the rosy hue, and the snow, ships, and entire scenery, became warmly illuminated until his whole disc had risen; then the usual grey tints of morning assumed their accustomed place, the scene becoming doubly desolate by a fall of snow. This meteor was seen by Lohrmann, at Dohna, near Dresden, on the 8th of June 1824, at 8 P.M.; it was visible in other parts of Germany, and frequently afterwards the same phenomenon was witnessed. The sun was setting behind the mountains when a luminous column 1° wide and 30° high, rose above the position of his disc; it continued some time, and rapidly disappeared in the shades of night. Professor Kämtz[3] had an opportunity of studying this meteor in January 1838, when the sun was preceded by a column about 10° high, which continued for several hours; when he had mounted 6°, an analogous band was observed beneath his disc, with this peculiarity, that the lower column appeared to reach the ground where the observer was standing. The phenomenon lasted till about noon; during its continuance, a portion of the halo whose radius is 22°, was once noticed in the east. Numerous spiculæ of snow were floating in the atmosphere at the time. Professor Christie[4] mentions having several times observed, in the south of England, a vertical yellow ray extending upwards from the sun, of the same diameter throughout, and rising to an altitude of 30°, diminishing in brightness with its altitude. Lord Valentia[5] mentions having seen the sun set at Mocha in Arabia, in

[1] Ann. of Phil. xx. 223. [2] Jour. Lond. 1824. [3] Kämtz and Martins,—Met.
[4] Brit. Assoc. 1837: Athen. No. 519, p. 747, Oct. 7. 1837.
[5] Trav. vol. ii. p. 359.

the semblance of a flaming column, having lost his spherical form; and Agatharcides,[1]—"nec sol ab disci formam se habet, sed crassam refert columnam principio." The same phenomenon is described by Mrs Elwood,[2] as seen at Cosseir on the Red Sea.

Although some of these meteors are most probably electrical, others are caused by reflexions of light from the snow-crystals floating in the atmosphere. The suggestion of Christie and Lubbock, that the vertical columns at sunset seen in this country, arise from reflexions upon an undulating stratum of liquid air in the higher regions of our atmosphere, seems, together with the hypothesis of Poisson,[3] upon which it rests, altogether untenable. In establishing this theory of the condition of the upper stratum of our atmosphere, besides the difficulties to be overcome in the possibility of obtaining a liquid atmosphere from cold alone,—such as that of the temperature of space,—there are optical objections sufficient to overturn the hypothesis. We would not close this section without referring to the curious optical phenomenon of *Blue suns.* These have been frequently observed in the West Indies, Africa,[4] over the whole of Italy, and the south of France. Babinet has suggested an explanation which Brewster has adopted. The phenomenon appears to depend upon the presence of vesicular vapour in the atmosphere, the different media of which, produce upon light in its passage, effects similar to those of *mixed plates.*[5] It may be imitated by soap lather between plates of glass, the bubbles representing the vesicular globules through which the light passes, in media having different degrees of refrangibility.

[1] Hudson,—Geog. Minor. Agathar.; Diodor. lib. iii. cap. 3; Crichton's Arab. vol. i. p. 74,—Ed. Cab. Lib.

[2] Trav. in Egypt, 1830.

[3] Traité de Mécanique, tom. ii. p. 612; Théorie Math. de la Chaleur, p. 460; Athen. No. 519, p. 743.

[4] Rozet,—Voy. dans la Régence d'Alger.

[5] Athen. Sept. 21. 1844.

CHAPTER XI.

273. The Looming. 274. Mirage,—its cause. 275. Curious refraction of coast of France; of Dover castle. 276. Figures in the air; Spectre of Souter-fell. 277. Spectral ships. 278. Remarkable mirage at Birkenhead. 279. Singular atmospheric refractions on the Geneva lake. 280. Fog-banks. 281. Fata Morgana. 282. Curious mirages at Youghall. 283. Appearance from Brighton Cliff; and Etna. 284. Enchanted coast. 285. See-kote. 286. Chittram, or Sehrab of the Desert. 287. Witnessed in India. 288. Iceblink. 289. Spectre of the Brocken. 290. Spectre of Skiddaw, and Ben Lomond.

"Far distant images draw nigh."
WORDSWORTH,—*Evening Ode.*

"Fierce fiery warriors fight upon the clouds,
In ranks, and squadrons, and right form of war."
Julius Cæsar, act. ii. sc. ii.

273. The *Looming* is an unusual atmospheric refraction presenting an apparent increased elevation of objects. The phenomenon may be observed towards the close of a warm summer day, when the hills in the distance seem greatly magnified. Mrs Somerville[1] makes mention of the chain of the Himalayas having started into view to a spectator on the plains of Hindostan, after a heavy shower following a lengthened drought. Walls[2] witnessed this phenomenon at Hudson's Bay, in 1769; and Scoresby[3] mentions that points on the coast of Greenland, distant 160 miles, could sometimes be distinctly seen, though not more than 4000 feet high. In the antarctic regions the same phenomenon has been seen; thus Sir James C. Ross[4] observes,—"During the afternoon, an un-

[1] Connex. Phys. Sc. sect. 18, p. 184, 2d ed.
[2] Thomson's Hist. Roy. Soc. 4to, p. 229.
[3] Journal, pp. 106–108.
[4] Voy. of Discovery.

usual degree of refraction was remarked to the south-westward, which had the effect of bringing at times clearly into view land which we had not before seen, and then again removing it from our sight." This land, then 100 miles distant, was Cape Anne. Upon the 21st of June 1819, at 8 P.M., the thermometer being 44°, when Captain Colby[1] and Lieutenants Robe and Dawson, R.E. were ranging the Caithness coast with a theodolite telescope, from Corryhabbie hill in Banffshire,—elevated not more than 2550 feet above the sea,—they distinctly saw a brig sailing to the westward, in the Pentland Frith, between Dunnet and Duncansby Heads; the ship was then from 90 to 100 miles distant. The night and day preceding the phenomenon had been continually rainy and misty; the clouds continued on the hill till seven o'clock that evening. Professor Lloyd[2] mentioned to the British Association in 1837, that he had seen from Dublin, the Welsh hills from their very valleys, so distinctly, that the larger inequalities on the surface of the mountains were vividly depicted. The atmosphere was then clear and loaded with invisible moisture, for immediately thereafter it rained heavily. Sir David Brewster conjectures, that on such occasions the intervening air actually becomes a magnifying lens of large proportions. Travellers in the desert have often been deceived by the same phenomenon, into the belief that they were approaching a stately tree, when it was merely a tiny shrub, and thus their hopes of shelter from an ardent sun and burning desert, have been painfully disappointed.[3]

M. Delcros,[4] while making a barometrical measurement of the profile of Mount Jura, in 1813, found that atmospheric refraction was modified by horary circumstances, and that with singular constancy,—leading him to say that the coefficient of refraction was only constant in its inconstancy. This led to a daily exhibition of the looming, more regular, however, than that phenomenon generally occurs. In the morning, the

[1] Ed. Phil. Jour. vol. i. p. 411.

[2] Brit. Assoc. 1837; Athen. No. 517, p. 692.

[3] Tod's Annals and Antiq. of Rajasthan or Rajpootana, 4to, Lond. 1829-32.

[4] Bibliotheque Univ. vii. Mar. 1818; Ann. of Philos. xii. 364, plate.

signal on the Oberhergheim was invisible from his station near Ensisheim in Alsace, neither could he detect an enormous poplar which grew near it. About 3 P.M., however, he began to perceive the top of the tree above the horizon ; soon thereafter the black ball of the signal appeared, and then its entire pyramid of twenty metres elevation, which was visible till five o'clock. Towards evening another change took place ; the signal looked like a very obtuse pyramid on the top of an apparent hill, produced by refraction from the plain, and the poplar was reduced to a diminutive size,—the phenomenon now disappeared, and till next day after noon, the signal was not seen.

274. When the object appears inverted, the French and Italians designate the phenomenon Mirage and Fata Morgana, described so early as the 17th century by the learned Jesuit Kircher. The greater number of these singular meteors arise from the irregular refraction of light passing through strata of air of unequal density ; through such media, the rays will be bent in curves, the convexity being upwards when they pass above that portion of the atmosphere which is most dense, and downwards when below that stratum, producing an elevated appearance of the object, and by the entrance of a double pencil of rays, an inverted image : others depend upon the reflexion of objects upon dense fogs strongly illuminated. We shall notice some of the most interesting of these phenomena.

275. Mr Latham, F.R.S., on the 26th of July 1798, at 5 P.M., had his attention drawn to a beautiful appearance of the mirage witnessed at Hastings, by the numbers of persons running to the beach to behold the wonder. The coast of France, from Calais to Dieppe, had become distinctly visible, and the fishermen were pointing out and naming the places wont to be visited by them. By help of a glass the fishing-boats were seen at anchor off the French coast; Dungeness, which is 16 miles from Hastings, and runs two miles into the sea, was apparently close at hand, and the vessels sailing were much magnified ; the phenomenon lasted till sunset. On the 6th of August 1806, about 7 P.M., Dr Vince when at Ramsgate,

saw the *whole* of Dover Castle, as if upon the Ramsgate side of a hill which obscures the castle, excepting the turrets, from that town. Between Ramsgate and the land from which the hill rises, almost six miles of sea intervene, and about the same distance thence to the castle, which stands upon a cliff about 320 feet above the sea. During the continuance of this beautiful mirage, the castle was so vividly depicted that the hill did not itself appear through the image.[1]

276. Analogous to this, is the remarkable appearance of troops of soldiers and horsemen exercising in the air, or reflected to the opposite side of the hill where they are assembled.[2] One of the earliest records of this phenomenon is given by Josephus,[3] on the testimony of several witnesses. There were seen, says he, on the 21st of the month Artemisius[4], shortly after the pascal feast, up and down the air before sunset, chariots and armed men, all over the country, passing along with the clouds round about the city. Holinshed[5] records several instances, some of which were doubtless auroræ boreales. Upon the 4th of October 1835, a phenomenon of this kind was seen at Chewton, on one of the Mendip hills in Wilts, about 6 P.M. It represented a large body of troops moving onwards with drawn swords; their position and space were often changed, and so distinctly were they visible, that the very trappings of the horses, and the several accoutrements of the soldiers, could be distinguished; the phenomenon lasted above an hour. It was afterwards ascertained that a body of yeomanry were practising about fifteen miles off. A similar appearance, which has been called the *spectre of Souter-fell*, is thus described by Mr James Clark.[6] "On a summer's evening in the year 1743, when Daniel Stricket, servant to John Wren of Wilton Hall, was sitting at the door along with his master, they saw the figure of a man with a

[1] Ed. Roy. Tr. vol. vi. p. 245.

[2] See "An Alarm to a Secure Generation," by John Howie of Lochgoin, 1780, where many visions are recorded.

[3] Joseph. Wars of the Jews, vii. 12; L'Estrange's Trans. fol. 547.

[4] Iyar or Zif, *i.e.* Apr. or May.

[5] Chron. vol. ii. pp. 59, 132, vol. iii. pp. 220, 249, 395, 773, 1313.

[6] Survey of Lakes of Cumberland.

dog pursuing some horses along Souter-fell side, a place so extremely steep that a horse could scarcely travel upon it at all. The figures appeared to run at an amazing pace, till they got out of sight at the lower end of the fell. On the following morning, Stricket and his master ascended the steep side of the mountain, in full expectation of finding the man dead, and of picking up some of the horse's shoes, which they thought must have been cast, while galloping at such a furious rate. Their expectations, however, were disappointed. No traces either of man or horse could be found, and they could not even discover upon the turf the single mark of a horse's hoof. These strange appearances, seen at the same time by two different persons in perfect health, could not fail to make a deep impression on their minds. They at first concealed what they had seen, but they at length disclosed it, and were laughed at for their credulity.

"In the following year, on the 23d June 1744, Daniel Stricket, who was then servant to Mr Lancaster, of Blakehills, a place near Wilton Hall, both of which places are only about half a mile from Souterfell, was walking about seven o'clock in the evening, a little above the house, when he saw a troop of horsemen riding on Souterfell side, in pretty close ranks, and at a brisk pace. Recollecting the ridicule that had been cast upon him the preceding year, he continued to observe the figures for some time in silence; but being at last convinced that there could be no deception in the matter, he went to the house and informed his master that he had something curious to shew him. They accordingly went out together, but before Stricket had pointed out the place, Mr Lancaster's son had discovered the aërial figures. The family was then summoned to the spot, and the phenomena were seen alike by all of them. The equestrian figures seemed to come from the lowest parts of Souterfell, and became visible at a place called Knott. They then advanced in regular troops along the side of the fell till they came opposite to Blakehills, when they went over the mountain, after describing a kind of curvilineal path. The pace at which the figures moved was a regular swift walk, and they continued to be seen for upwards of two hours, the approach of darkness alone

preventing them from being visible. Many troops were seen in succession; and frequently the last but one in a troop quitted his position, galloped to the front, and took up the same pace with the rest. The changes in the figures were seen equally by all the spectators, and the view of them was not confined to the farm of Blakehills only, but they were seen by every person at every cottage within the distance of a mile, the number of persons who saw them amounting to about twenty-six. The attestation of these facts, signed by Lancaster and Stricket, bears the date of 21st July 1785."

277. On the 1st of August 1798, between four and eight P.M., Dr Vince[1] saw a ship in the offing off Ramsgate, the sails of which were merely visible above the waves. At the same time, an inverted image of the whole vessel appeared below one of the real ship, their hulls appearing joined. As the ship receded, less of it became visible, while the spectral images at the same time appeared to ascend. Directing his telescope to a vessel full in view, he beheld an inverted representation above, the masts in this case seeming to touch; but he saw no other figure above. There happened to be another vessel in view, the hull of which merely was hid. Some portions of the rigging were seen inverted, but they were not constant, appearing and disappearing suddenly. He watched the effect of this peculiar state of the atmosphere upon another vessel which was then in the horizon, with the top mast only visible. An inverted image appeared, as in all the other instances, vertically above it, and above that an erect picture, with a portion of sea between the images; this mirage remained visible when the entire ship had disappeared. Upon the 17th of the same month, about 3.5 P.M., he observed the approach of a vessel to the horizon, by noticing an inverted image of its hull and portion of the sails above the waves, and an erect image of the ship above that. Huddart,[2] in 1793, at Allonby in Cumberland, had perceived an image of a vessel in the sky, with an inverted figure of the same beneath. Scoresby,[3] in the Arctic Sea, observed, on the 28th of June 1820, towards 6 P.M., about eighteen or nineteen ships at the

[1] Phil. Trans. 1799; see also ib. 1800,—Wollaston.

[2] Phil. Trans. 1797.

[3] Journal, 8vo, 1823.

distance of ten or fifteen miles; from the mast-head he saw them change form, one being drawn out or elongated in a vertical plane, another contracted in the same direction; one had an inverted image immediately above it, and two had two distinct inverted images in the air; along with these, there appeared images of ice in double strata, the highest having an altitude of 15′. The sky had been cloudless during the day, and the sun's rays powerful; before the phenomenon appeared a slight breeze had sprung up. On another voyage, in 1822, when searching for his father's ship, he recognised it, though still below the horizon, from an inverted image in the air. "It was," says he,[1] "so well defined, that I could distinguish by a telescope every sail, the general rig of the ship, and its particular character; insomuch that I confidently pronounced it to be my father's ship the *Fame*, which it afterwards proved to be, though, in comparing notes with my father, I found our relative position at the time gave our distance from one another very nearly thirty miles, being about seventeen miles beyond the horizon, and some leagues beyond the limit of direct vision. I was so struck by the peculiarity of the circumstance, that I mentioned it to the officer of the watch, stating my full conviction that the Fame was then cruising in the neighbouring inlet." A mirage was witnessed off the coast of Kent by Professor J. D. Forbes,[2] on the 31st of July 1826, at 5.5 P.M.—the ships were twice refracted.

Rozet[3] mentions a mirage not unlike this, which he witnessed in Algeria, on the 27th June 1830, at 10 A.M. Looking along the line of soldiery, he beheld above the troops, a second line exactly similar, more faint, but perfectly visible. The ball and crescent on the Algerine tents appeared doubled. It looked like the double image seen through iceland-spar. The same phenomenon he had seen before, in France, when the temperature was low, and it was not the only time he witnessed it in Africa.

278. Analogous to these phenomena, was the mirage wit-

[1] Journal, 8vo, p. 189.
[2] Edin. Jour. of Sc. vol. ix. p. 132.
[3] Voy. dans l'Alger.

nessed upon the morning of the 18th June 1846, on the shore of the Sound between Vedbek and Rongsted near Copenhagen. The Island of Huen or Hveen seemed flying in the offing, and even disappeared, while the opposite coast of Sweden (Scania) appeared so near, as to be almost tangible; the ships at sea were inverted, sailing with their keels uppermost and their masts touching the waves; the phenomenon lasted an hour. Upon the 27th September, same year, about 3 P.M., a very extraordinary mirage was witnessed from Clifton Park, Birkenhead, on the Cheshire coast of the Mersey. The author was favoured with an account of the phenomenon from an observer, to whose polite reply to his inquiries he begs to tender acknowledgments. The astonishment of those who were so fortunate as to behold this unique mirage, must not have been slight, when they witnessed in the sky above Liverpool, an image of Edinburgh! The day had been warm, and the sky was serene, with light grey clouds in the horizon, upon which the enchanting scene was depicted. The principal places in the city were most distinct and clear, and seemed as if laid out by the painter. The mirage continued nearly an hour, and what is curious, the figures were *erect.* Gazing with delight and wonder at the fairy scene, it was recollected that at that time a large panoramic model of Edinburgh was being exhibited in the open air by the side of a pond in the Zoological Garden of Liverpool, opposite to Birkenhead. The scenic representation of the Scottish capital was painted in oil, on one side only, and was in different pieces, the front view of which presented an angle of nearly 45° to the river. The model was a good representation of Edinburgh, and the aërial picture could not be mistaken, especially by those who were familiar with the real city.[1] Upon the 16th July 1820, about 4.5 A.M., while the sun was shining in a cloudless sky, and a light haze from the Ouze, was hovering over a little hill near St Neot's, an aërial picture of Great Paxton, with its grass fields, trees, cottages, and farm-houses, was depicted with much distinctness upon the vapour; the phenomenon extended

[1] Author,—Brit. Assoc. Rep. 1847.

from east to west about 400 yards, and continued for ten minutes.[1]

279. A singular unusual atmospheric refraction was witnessed on the Leman Lake, by MM. Jurine and Seret,[2] on September 17. 1818, about 10 P.M. A vessel about 4000 toises from Bellerive, appeared making for Geneva by the *left* bank of the lake, moving from N. to S., while, at the same time, an image of the sails of this bark was seen above the water, but instead of following the direction of the vessel, separated from it, and approached that city by the *right* bank, moving from E. to W. As the spectre receded from the true ship, it diminished in size till, when reduced one-half, it disappeared. In this case of lateral reflexion, the strata of similar density must have been *vertical*, or latterly contiguous, for had they been horizontal or superimposed, the image would have been represented above, and it then would have been, what has been called, a mirage of suspension. An interesting mirage, combining the phenomena of vertical and lateral reflexions, has been described by Blackadder,[3] as witnessed at Leith from King George's Bastion. The "Phantom-Ship" of Washington Irving, and the "Flying-Dutchman" of others, are spectra produced by abnormal refractions. By the same cause the tops of mountains in the polar circle, have been seen to meet so closely, as to present the semblance of a huge arch. Among the Western Isles of Scotland, fairy castles and verdant fields are not unfrequently observed upon the barren rocks; they are also familiarly known to the Irish peasantry.

280. Doubtless the "fog-bank" of the sailor, mistaken for *terra firma*, has unwittingly found a place upon the chart;—shall we not say that this has been the case, even in these present times, by an able and adventurous mariner of a neighbouring country, while ploughing the antarctic deep? Such was the fairy island in the Atlantic between Ireland and Newfoundland, which for centuries, even to 1750, perplexed

[1] Cambr. Chron.; Ann. Philos. xvi. 149.
[2] Jour. de Phys. Mar. 1820, tom. 90, p. 217.
[3] Ed. Jour. of Sc. vol. iii. p. 13; Ed. Encyc. vol. xvii. 590.

navigators with its sudden appearance and defiance of all attempts to reach its shores. Well might it be called in these dark ages the "Isle of Ghosts," the "Country of Spirits," the "Enchanted Island," or simply the "Country in the Waves," —Brasil of the French, Assmunda of the Spanish. Ortelius,[1] the geographer, contemporary of Mercator, mentions it; and De l'Isle places it upon his map.

281. The *Fata Morgana*, or Dama-fata-morgana[2] witnessed in the straits of Messina, is thus described by Father Angelucci,—"On the 15th August 1643, as I stood at my window, I was surprised with a most wonderful and delectable spectacle. The sea that washes the Sicilian shore swelled up, and became for ten miles in length like a chain of dark mountains; whilst the waters on the Calabrian shore grew quite smooth, and in an instant appeared as one clear polished mirror, reclining against the ridge. On this was depicted in *chiaro-scuro*, a string of several thousand pilasters, all equal in altitude, distance, and degree of light and shade. In a moment they lost half their height, and bent into grades like Roman aqueducts. A long cornice was next formed upon the top, and above it rose innumerable castles, all perfectly alike. These soon split into towers, which were shortly afterwards lost in colonnades, then ended in pines, cypresses, and other trees, even and similar. This is the *fata morgana*, which for twenty-six years I thought a mere fable." To observe this curious mirage, the spectator must occupy an elevated situation behind the city, looking to the west; his view then extends over the whole bay, and the Sicilian hills form a back ground to the landscape. The tide is rising high, and the water, unruffled by the breeze, is elevated by currents in the midst of the channel; the sun has mounted above the hills, and forms an angle of 45° with the sea before Reggio; every object is now reflected in this marine mirror, and as the sun advances the figures gradually vanish.[3] Antonio Minasi observes that if, in addition to the circumstances which produce the reflexion in the water, "the atmosphere be highly im-

[1] Thesaurus. [2] Swinburne,—Trav.
[3] Biot,—Astron. Physique.

pregnated with vapour and dense exhalations, not previously dispersed by the action of the wind and waves, or rarefied by the sun, it then happens, that in this vapour, as in a curtain extended along the channel to the height of about five-and-twenty feet, and nearly down to the sea, the observer will behold the scene of the same objects not only reflected from the surface of the sea, but likewise in the air, though not so distinct or well defined as the former objects from the sea." Lamartine[1] has given a poetic description of the phenomenon. A mirage somewhat similar, clear and distinct as the image reflected in a glass, was witnessed at Stralsund in Pomerania, on the 28th of July 1846, at 3.5 A.M. It appeared upon the shore about a mile from the town, as an image of Stralsund, depicted in a deep blue on an opal ground, upon the opposite coast of the Isle of Rugen. It was reversed, appearing exactly as the town does from that Island. The façade of the old Gothic church of St Mary, was given with the precision and minuteness of a photographic picture: it seemed to want only the mercurial fumes to give permanence to the magic performance. The phenomenon lasted about twenty minutes, dissolving in the increasing radiance of the sun, as his disc emerged from the Baltic.

282. The mirage is frequently the consequence of the interposition of transparent vapour, producing, by refraction as through a lens, a representation of an object, either of gigantic magnitude or dwarfish size, as the opposite surfaces of the vapour are convex or concave ; the object may be multiplied at the same time, if the surfaces are composed of planes differently inclined, an effect which may arise also when the vapour-bank is beyond the object reflected. Such a mirage occurred in 1787, at Kildare, where a house and garden refracted through vapour arising from a bog, appeared upon a field in the semblance of a hill clad with wood and dwellings. Others were seen at Youghall in Cork, on the 21st October 1796, and 9th March 1797. On the former occasion, the phenomenon was seen about 4 P.M. while the sun was shining clearly. "It appeared on a hill, on the county

[1] Trav. in East.

of Waterford side of the river, and seemed a walled town with a round tower, and a church with a spire; the houses perfect, and the windows distinct. Behind the houses appeared the mast of a ship, and in front a single tree, near which was a cow grazing; whilst the Waterford hills appeared distinctly behind. In the space of about half an hour the spire and round tower became covered with domes, and the octagonal building, or rather round tower, became a broken turret. Soon after this change, all the houses became ruins, and their fragments seemed scattered in the fields near the walls: the whole in about an hour disappeared, and the hill on which it stood sunk to the level of the real field. The hill and trees appeared of a bright green, the houses and towers of a clear brown, with their roofs blue."[1] On the second occasion, the mirage appeared about 8 A.M. to the S.E. of Youghall. Its features were very much like the last, only it was seen at sea as if upon a rock; the water was calm, the morning serene, and greatly to the additional beauty of this fairy castle, was the fact, that ships seemed to pass behind it. In June 1801, about 5 A.M., another interesting mirage was witnessed at the same place. "All the coast opposite the river Youghall, on the Waterford side, was covered with a dense vapour; that on the right next the sea had the representation of an alpine country; the distant scarpy mountains seemed covered with snow, while the foreground, of a brown colour, resembled woods and a cultivated country. Soon the snow was seen to roll down the sides of the mountain into the valleys beneath, and left the grey rocks of the mountains naked and sharp. As the sun increased in power, the vapour vanished. On the left, the river and adjacent country were also covered with a vapour, but of quite different appearance from the former. The country seemed laid out in lawns and improvements in which were situated three gentlemen's seats; the houses well defined, the windows and doors distinct. From the houses were beautiful shrubberies bordered with white paling; behind were forests of pines; and distant mountains, in fine perspective, closed the scene. Before the

[1] Curios. for the Ingen. Lond. 1822.

houses in the lawns were clumps of forest-trees. In about half an hour two of the houses vanished, and the clumps in front disappeared, and in their place a fine oak sprang up, which was the last object that quitted the scene."

283. Analogous to these phenomena, was the singular aërial spectacle witnessed by Dr Buchan[1] on the cliff at the east of Brighton, on the 18th November 1804. The rock on which he stood, with the figures of himself and his companion upon its top, were represented at a distance upon the ocean, between him and the sun, then just emerging from the waves. The Rev. Mr Hughes[2] mentions that when he and several spectators were upon the summit of Mount Etna, a miniature image of the mountain was seen depicted upon the apex of a gigantic shadow of the volcano projected across the island, and elevated above the horizon. It was visible ten minutes and disappeared as the shadow lessened: such spectra, he observes, are familiar to the Catanians. It is not clear that this spectre was an image of *Etna;* it has been suggested by Mr Blackadder[3] that it might have been Malta, or Pontellaria, seen through the influence of unequal refraction.

284. A curious and beautiful atmospheric refraction seen in the polar regions, has been happily termed the "Enchanted Coast."[4] Scoresby thus describes it,—"The general teles copic appearance of the coast was that of an extensive ancient city, abounding with the ruins of castles, obelisks, churches, and monuments, with other large and conspicuous buildings. Some of the hills seemed to be surmounted with turrets, battlements, spires, and pinnacles; while others, subjected to one or two reflexions, exhibited large masses of rock, apparently suspended in the air, at a considerable elevation above the actual termination of the mountains to which they referred. The whole exhibition was a grand phantasmagoria. Scarcely was any particular portion sketched before it totally disappeared. It was, perhaps, alternately a castle, a cathedral, or an obelisk; then expanding horizontally, and coalescing with

[1] Nicholson's Journal, vol. xiv. p. 340.
[2] Trav. in Greece, &c., 4to. 1820.
[3] Ed. Jour. of Sc., vol. v. p. 227.
[4] Crantz,—Hist. Greenland; Scoresby,—Jour. pp. 96, 143, 166; Arct. Reg.

the adjoining hills, united the intermediate valleys, though some miles in width, by a bridge of a single arch, of the most magnificent appearance and extent. Notwithstanding these repeated changes, the various figures represented had all the distinctness of reality ; and not only the different strata, but also the veins of the rocks, with the wreaths of snow occupying ravines and fissures, formed sharp and distinct lines, and exhibited every appearance of the most perfect solidity."

285. But this singular spectacle is not wholly confined to the frigid regions of our globe. In India, an analogous phenomenon, termed by the natives *see-koté*, and *dessasur*—i. e. *cold weather castles*, and *the omen of the quarter*—has been observed. Col. Tod[1] and others, have described this mirage. It appears when the thermometer is low—even at zero,—and in this respect differs from the *chittram* or *sehrab*—the mirage of the desert. Objects are presented at first, near and greatly magnified ; changes then take place in the delusive picture, towers, castles, and pinnacles start up as if by enchantment, and die away like a dissolving view, under the increasing power of the rising sun. "It was at Hisar," says Col. Tod, "on the terrace of a house built amidst the ruins of the castle of Foroy, in the centre of one extended waste, where the lion was the sole phenomenon. It was really sublime. Let the reader fancy himself in the midst of a desert plain, with nothing to impede the wide scope of vision, his horizon bounded by a lofty black wall, encompassing him on all sides. Let him watch the forest sunbeam break upon this barrier, and at once, as if by a touch of magic, shiver it into a thousand fantastic forms, leaving a splintered pinnacle in one place, a tower in another, an arch in a third, these in turn undergoing more than kaleidoscopic changes until the 'fairy fabric' vanishes. Here it was emphatically called *Hurcheend Raja ca poori*, or the city of Raja Hurcheend, a celebrated prince of the brazen age of India. The power of reflexion shown by this phenomenon cannot be better described than by stating, that it brought the very ancient Aggaroa, which is thirteen

[1] Antiq. of Rajasthan ; Lichenstein,—Trav. in Southern Africa ; Edin. Rev. vol. xxi. pp. 66, 138.

miles distant, with the fort and bastions, close to my view." As the day advances, and the atmosphere becomes excessively heated, a scene somewhat similar is often witnessed in the same regions. Such a mirage is thus described by the late Capt. Basil Hall :—" The trees and shrubs seen under a variety of refractions, through differently heated strata of air, seemed all in violent motion, though probably not one leaf of the highest cocoa-nut tree, nor a single blade of the lowest grass, stirred in reality. The buildings in the distance looked as if their foundations had been removed, while the shattered and broken walls danced to and fro, as if under the influence of some magical principles of attraction and repulsion ; whilst many patches of imaginary water floated where no water could have existed, mocking our sight in this fantastic landscape." Humboldt[1] informs us, that in the *llanos* of South America, at Cumana, on the sterile *steppes* of the Caracas, and by the Orinocco, where the air is dry, he often witnessed these singular atmospheric refractions, exhibited in the figures of oxen suspended in the air, and this, long before the herd was visible ; likewise, in images of the islands of Picuita and Boracha, floating in the atmosphere. Niebuhr[2] witnessed the same in Arabia.

286. The Arabs are rarely deceived by the *mirage of the desert*,[3] but when real water exists, and a mirage is visible at the same time, it is not easy to distinguish the true from the false.[4] The traveller, should he be not undeceived, quickens his wearied pace, that he may quench his thirst in what seems a beautiful lake.[5] As already observed, this mirage depends upon the undulating motion given to the air by the highly heated surface of the ground ; should a perfect calm prevail, and the mass of air upon the ground remain at rest while the lower strata are being heated, the mirage rises, distant objects are not broken and distorted, and inverted images appear below, like their reflexions in a lake. To the French army in Egypt, this mirage was a source of constant illusion, and

[1] Voy. aux Rég. Equinox. [2] Voy. en Arabie.

[3] *Sehrab*, or water of the desert; *Mriga-trichna*, thirst of the antelope,—Sanscrit.

[4] Lyon,—Northern Africa, p. 347.

[5] Shaw,—Trav. p. 378; Belzoni,—Nar. 3d Ed. vol. i. p. 304; &c.

not unfrequently severely tantalized the soldiery.[1] "During the whole day's march," says Burckhardt,[2] "we were surrounded on all sides by lakes of mirage, called by Arabs *serab.* Its colour was of the purest azure, and so clear that the shadows of the mountains which bordered the horizon were reflected in it with the greatest precision, and the delusion of its being a sheet of water was thus rendered still more perfect. I had often seen the mirage in Syria and Egypt, but always found it of a whitish colour, rather resembling a morning mist, seldom lying steady on the plain, but in continual vibration; but here it was very different, and had the most perfect resemblance to water. The great dryness of the air and earth in this desert may be the cause of the difference. The appearance of water approached also much nearer than in Syria and Egypt, being often not more than 200 paces from us, whereas I had never seen it before at a distance of less than half a mile. There was at one time about a dozen of these false lakes around us, each separated from the other, and for the most part in the low grounds." The Rev. Robert Moffat,[3] travelling through the Griqua country in Southern Africa, met with a mirage, called by the Bechuanas, *moénéne,* which he thus describes:—"We now directed our course towards Witte Water, where we could scarcely hope to arrive before afternoon, even if we reached it at all, for we were soon obliged to dismount, and drive our horses slowly and silently over the glowing plain, where the delusive mirage tantalized our feelings with exhibitions of the loveliest pictures of lakes and pools studded with lovely islets, and towering trees moving in the breeze on their banks. In some, might be seen the bustle of a mercantile harbour, with jetties, coves, and moving rafts and oars; in others, lakes so lovely, as if they had just come from the hand of the Divine Artist, a transcript of Eden's sweetest views, but all the result of highly rarefied air, or the reflected heat of the sun's rays on the sultry plain. Sometimes, when the horses and my companions were several hundred yards in advance, they appeared as if lifted from the earth, or moving like dark living pillars in the air." Mr Rae

[1] Monge,—Mém. sur l'Egypte. [2] Nubia, p. 193. [3] S. Africa, ch. xi.

Wilson observes—"About three o'clock, I perceived the turrets and sycamore trees of Rosetta, at which time I found myself greatly exhausted from oppressive heat and fatigue; and, like other travellers, was deceived by the mists and apparitional lake so celebrated under the name of the mirage or *al serab*, the illusory lake of the desert, which even at a very short distance had the most perfect resemblance to a vast sheet of water, with trees planted in it at certain distances, and reflecting every surrounding object as a mirror. We fancied this watery wilderness to be an unsurmountable barrier to our reaching Rosetta, and that our guide had mistaken the proper track through the desert; but as we advanced, the supposed lake and its objects vanished,—so powerful was the delusion."

287. This phenomenon is noticed by several Indian travellers. The Hon. Mr Elphinston[1] remarks:—"We had made a march of thirty miles to Moujgur; the heat of the afternoon was intense; while we halted as usual in the naked plain to give our people some water, and to take some refreshments ourselves. In the course of the day, several hundred skins of water came to us from Moujgur, where Bahawal Khan had sent his principal officers to receive us. Towards the evening, many persons were astonished with the appearance of a long lake enclosing several little islands. Notwithstanding the well-known nature of the country, many were positive that it was a lake, and one of the surveyors took the bearing of it." In reference to the same meteor, seen at the Shallout Pass in India, Mundy[2] thus writes:—"A deep precipitous valley below us, at the bottom of which I had seen one or two miserable villages in the morning, bore in the evening a complete resemblance to a beautiful lake; the vapour which played the part of water, ascending nearly half way up the sides of the vale, and on its bright surface trees and rocks being distinctly reflected." Quintus Curtius[3] refers to this phenomenon in the Sogdian desert; and it is mentioned in the Koran,[4]—"But

[1] Account of Cabul. [2] Jour. of Tour in India.

[3] Lib. viii. cap. v. near beginning.

[4] Koran, ch. xxiv., and note,—Sale; Isaiah xxxv. 7.—Lowth's Transla., note; Ib. xli. 18; Psal. cvii. 35; Jer. xv. 18, marginal reading.

as to unbelievers, their works are like a vapour in a plain; which the thirsty traveller thinketh to be water, until when he cometh thereto, he findeth it to be nothing." The Arabian and Persian writers often describe the magical effects of the mirage, in the glowing language of eastern tale.

288. The *iceblink* of the Dutch, described by Scoresby, Ross, Parry, and others, is another effect of unusual refraction, by which an open sea and the *quality* of the ice may be discovered, though many leagues beyond the sphere of vision. It appears in the offing, as a chalk-white streak, when the light is reflected from *pack-ice*,—or ice in which no opening can be detected from the mast-head,—but when the glare arises from *snowfields*, the blink is slightly tinged with yellow.

289. In describing *glories*, we referred to the curious phenomenon of shadows cast upon clouds and mists. These are often of gigantic size, and in Germany especially, are associated in the minds of the peasantry with the work of fairies and hobgoblins. The *Brockenge-spenst*, or Spectre of the Brocken, and the Spectre of the Rigi, are familiar examples. Upon the summit of the Brocken, the highest of the Hartz mountains, elevated above the sea about 3540 feet, there is a small inn, the Brockenhaus, which, when the circumstances are favourable to the exhibition of the phenomenon, is magnified upon the cloud to the size of a castle, and the spectator to that of a giant, "extending to the length of five or six hundred feet, at the distance of about two miles before him,"—Haüy. Should there be several individuals upon the Brocken at the time, the effect is very curious, for when they change their positions or make certain gestures, the huge aërial figures go through the same evolutions. Numerous are the legends of the evil spirits of the Brocken, and of their annual conventicle on the *walpurgis-nacht*, when they renew allegiance to their master, and celebrate the festival in witch-like orgies! The *wraith* of the Highlander may probably depend upon a similar cause—the shadow of the individual projected upon a fog or cloud. This remarkable appearance[1] has been thus

[1] Vide Gmelin's Gotting. Jour. der Wissenchaften. 1798, vol. i. part iii.; Brewster,—Nat. Magic.

described by M. Haüy, who ascended the Brocken thirty times before he was gratified with the sight. It was on the 23d May 1797. "The sun rose about four o'clock, and the atmosphere being quite serene towards the east, his rays could pass without any obstruction over the Heiwrichshöhe. In the S.W., however, towards Achtermaunshöhe, a brisk west wind carried before it thin transparent vapours, which were not yet condensed into thick heavy clouds. About a quarter past four, I went towards the inn, and looked round to see whether the atmosphere would permit me to have a free prospect to the S.W., when I observed at a great distance, towards the Achtermaunshöhe, a human figure of a monstrous size. A violent gust of wind having almost carried away my hat, I clapped my hand to it, and the colossal figure did the same. The pleasure I felt on this discovery can hardly be described, for I had already walked many a weary step in hopes of seeing this shadowy image, without being able to gratify my curiosity. I immediately made another movement, by bending my body, and the colossal figure before me repeated it. I was desirous of doing the same thing once more, but my colossus had vanished. I remained in the same position, waiting to see whether it would return, and in a few minutes it again made its appearance. I paid my respects to it a second time, and it did the same to me. I then called the landlord of the Brocken. Having both taken the same position which I had taken alone, we looked towards the Achtermaunshöhe, but saw nothing. We had not, however, stood long, when two such colossal figures were formed over the above eminence, which repeated our compliments by bending their bodies as we did; after which they vanished. We retained our position, kept our eyes fixed on the same spot, and in a short time the two figures again stood before us, and were *joined by a third.* Every movement that we made by bending our bodies, these figures imitated, but with this difference, that the phenomenon was sometimes weak and faint, sometimes strong and well defined." It is to be regretted, that M. Haüy does not mention which of the two shadows was doubly copied when the third figure appeared. M. Jordan, in 1798, was witness of

the same phenomenon. "In the course," says he, "of my repeated tours through the Hartz mountains, I often, but in vain, ascended the Brocken, that I might see the spectre. At length, on a serene morning, as the sun was just appearing above the horizon, it stood before me, at a great distance, towards the opposite mountain. It seemed to me the gigantic figure of a man. It vanished in a moment." "The first time I was deceived," says Gmelin, "by this extraordinary phenomenon, I had clambered up to the summit of the Brocken very early in the morning, in order to wait there for the inexpressibly beautiful view of the sun rising in the east. The heavens were already streaked with red, the sun was just appearing above the horizon in full majesty, and the most perfect serenity prevailed throughout the surrounding country, when the other Hartz mountains in the S. W., towards the Worm Mountains, &c. lying under the Brocken, began to be covered by thick clouds. Ascending at that moment the granite rocks called Teufelskranzel, there appeared before me, but at a great distance, the gigantic figure of a man, as if standing on a large pedestal. Scarcely had I discovered it, when it began to disappear; the clouds sank down speedily, and I saw the phenomenon no more. The second time, however, I saw this spectre somewhat more distinctly, a little below the summit of the Brocken, as I was looking at the rising sun, about 4 A.M. The weather was rather tempestuous; the sky, towards the level country, was pretty clear, but the Hartz mountains had attracted several thick clouds which had been hovering around them, and which beginning to settle on the Brocken, confined the prospect. In these clouds, soon after the rising of the sun, I saw my own shadow, of a monstrous size, move itself for a couple of seconds exactly as I moved; but I was soon involved in clouds, and the phenomenon disappeared."

290. A similar phenomenon witnessed on Skiddaw, is thus described:[1]—"We set out late in a fine August night to reach the top of Skiddaw before sunrise; there was no moon, but the stars shone brilliantly, and as we rose up the steep hill

[1] Penny Magazine, July 31. 1837.

overhanging Applethwaite, the lake and valley became slowly more and more distinct in the cold leaden hue of early twilight. As often happens after the finest nights, the floating vapours were suddenly condensed; and by the time we reached the table-land near the top, we were enveloped in a thick white mist, cold and uncomfortable, which confined our sight to a circle of a few yards' diameter. Suddenly the white fog took a beautiful rose colour, produced probably like the last hues of evening, by the greater refractive power of the red rays, as the first beams of the sun shot above the horizon. This very soon vanished. One of the party was a short distance in advance when a ray of sunshine darted through the mist, and he saw a figure walking ten or fifteen yards distant from his side. Taking it for granted that this was one of his companions whom he had supposed at some distance, he vented some expressions of disappointment; and receiving no answer, repeated, and repeated it again. Still there was no answer, though the figure kept steadily advancing with even steps. At last he stopped, half angry, and turned quite round to look at his silent companion, who did the same, but receded as he approached; and it became evident, that the figure apparently dimly seen through the mist, was his own shadow reflected on it. It was then surrounded by a bright halo, and as the light became stronger, grew less and less distinct. The rest of the party came up in time to witness this remarkable appearance, with some modification. On reaching the ridge of the mountain, our figures of supra-human size appeared to be projected on the mist in the direction of the Solway."

A similar spectacle was witnessed on Ben Lomond, on the 19th August 1820, by Messrs Menzies and Macgregor.[1] "They reached the summit about half-past seven o'clock, in time to see the sun sinking beneath the western hills. Its parting beams had gilded the mountain tops with a warm glowing colour; and the surface of the lake, gently rippling with the breeze, was tinged with a yellow lustre. While admiring the adjacent mountains, hills and valleys, and the expanse of water beneath, interspersed with numerous wooded islands,

[1] Ed. Phil. Jour. vol. v. p. 218.

Mr Macgregor's attention was attracted by a cloud in the east, partly of a dark red colour, apparently at the distance of two miles and a half, in which he distinctly observed two gigantic figures, standing, as it were, on a majestic pedestal. He immediately pointed out the phenomenon to Mr Menzies, and they distinctly perceived one of the gigantic figures, in imitation, strike the other on the shoulder, and point towards us. They then made their obeisance to the airy phantoms, which was instantly returned: they waved their hats and umbrellas; the shadowy figures did the same. This phenomenon continued at least for about a quarter of an hour. A gentle breeze from the north carried the cloud in which it appeared slowly along; the figures became less and less distinct, and at last vanished." In December 1842, one of those interesting phenomena was seen by a gentleman near to Shaftesbury, Dorsetshire. The day had been foggy till about 3 P.M., when the sun burst out, illuminating the hill tops, while the mist still rolled in the valleys. At a point in the road in the direction of Wardour, to the S.W. of Salisbury, where it begins to descend, the observer saw his shadow of gigantic proportions depicted on the clouds, and imitating all his actions.

"Philosophy will—
Conquer all mysteries by rule and line,
Empty the haunted air and gnomed mine,
Unweave a rainbow."

CHAPTER XII.

291. Lightning,—ancient superstitions. 292. Electricity. 293. Electric tension of the atmosphere variable. 294. Schubler's experiments on electric precipitations. 295. Identity of lightning and electricity. 296. Franklin's discovery. 297. Death of Richman. 298. Remarkable scene witnessed by Crosse. 299. Electrolysis by lightning. 300. Light, heat, electricity, — probable identity. 301. Practical application of lightning. 302. Travellers electrified by induction. 303. Different kinds of lightning. 304. Thunder. 305. Thunder-storms in Tropics and mountainous districts. 306. Storm of 1st August 1846. 307. Lurid glare in the horizon. 308. Thunder without clouds. 309. Thunder in winter. 310. Singular electrical appearances in Java, Malta, &c. 311. Dangers of those in a row struck by lightning. 312. Ascending thunderbolt. 313. Descending thunderboldt. 314. Fulminary tubes. 315. Back-stroke. 316. Suggestions for safety. 317. Lightning protectors. 318. Theory of atmospheric electricity. 319. Sheet-lightning. 320. St Elmo's fire, Castor and Pollux. 321. Appearances at sea. 322. On land.

> "A common slave—
> Held up his left hand, which did flame and burn
> Like twenty torches joined; and yet his hand,
> Not sensible of fire, remain'd unscorch'd."
>
> *Julius Cæsar*, act i. sc. iii.

291. The luminous meteor about to be considered is perhaps the most awfully grand which can be witnessed. Lightning is a vivid flash, suddenly appearing and as quickly gone. Its speed is often made the mental comparison of greatest possible velocity : its actual velocity is infinitely more rapid than can be conceived, the apparent duration being entirely an optical impression upon the retina. The sky at the time of its appearance, is generally cloudy, though not always so, and the atmosphere for the most part is sultry. The ancient Greeks and Romans accounted lightning sacred, and they as-

sociated it with the wrath and indignation of their deities. To this our greatest English tragic poet refers, when he says,

> "Some innocents 'scape not the thunderbolt."
> *Antony and Cleopatra*, act ii. sc. v.

Ordinary sepulture was denied the bodies of those who unfortunately perished by its agency, and such spots as a thunderbolt descended upon, were sedulously shunned, being fenced round to protect the unwary from their contact. Appian mentions, that in Seleucia the thunderbolt was the chief divinity, and in his time received adoration. If the lightning darted on the right hand of the spectator, it was considered a happy omen, but if it appeared upon the other side, the presage was unfavourable; if it thundered while the sky was calm, the sign was good. Thus was Ulysses comforted,—

> "The pitying god his guardian aid avows;
> Loud from a sapphire-sky his thunder sounds;
> With springing hope the hero's heart rebounds."
> POPE,—*Odyssey.*

In those times, superstitious faith was placed in certain approved protectors from the thunderbolt. Thus, Pliny[1] informs us that the eagle, sea-calf, and laurel were in this respect efficacious; and Columella[2] adds the white vine. Suetonius[3] tells us, that Augustus[4] made choice of the sea-calf, and that Tiberius[5] bound his head with a laurel cincture when danger threatened. Of Caligula,[6] he says,—"Nam qui Deos tantopere contemneret, at minima tonitrua et fulgura connivere, capüt obvolvere, at vero majora proripere se è strata, sub lectumque condere solebat"! The thunder which accompanied, was accounted a terrestrial emanation, an idea which met the ridicule of Aristophanes.[7]

292. What electricity is, we know not. It is familiar to us only in its effects. We are ignorant whether it is a subtile matter of independent existence, or merely a new arrange-

[1] Hist. Nat. lib. ii. cap. lv.
[2] De Re Rustica, lib. x.
[3] Vitæ Duodecim. Cæsarum.
[4] In Vit. August. Op. Omn. lib. ii. cap. xc.
[5] In Vit. Tiberii, Ib. lib. iii. cap. lxix.
[6] In Vit. Calig. Ib. lib. iv. cap, li.
[7] The clouds.

ment of molecules; nevertheless, we speak of it as material, and call it the *electric fluid* or *electricity*. Numerous as crude were the theories of philosophers before the hypothesis of Franklin was promulgated. While he considered that it pervaded creation, he was disposed to think that friction changed its normal condition in bodies; hence arose the divisions, plus or *positive*, and minus or *negative* electricities. Another theory arose,—convenient but untenable,—that these electricities were altogether different, but both excited by friction,—the one with *resinous* substances, the other with *vitreous*, and termed accordingly, vitreous (+) and resinous (—) electricities: this was the theory of Dufay, which in this country received the support of Symmer.[1] The theories of its *unity* and *duality* for a time disturbed the harmony of the views of electricians, but the latter hypothesis, although sanctioned by Coulomb,[2] yielded to the truth-disclosing influence of time. Æpinus,[3] Cavendish,[4] and Van Marum[5] did much to further the views of Franklin. Peltier[6] has proposed a theory, which intimately connects the phenomena of electricity with those of light and heat, upon the undulatory hypothesis of these fluids. The *static* phenomena, he supposes to result from an undue proportion of electricity; the *dynamic*, to the re-establishment of electrical equilibrium between bodies unequally charged, by means of vibrations of this *electric ether*. Becquerel[7] leans to the undulatory theory of this fluid; and the discoveries of Faraday point strongly to such a conclusion.

293. Le Monnier, in 1752, observed that the atmosphere is generally in an electric condition, and in ordinary circumstances, the electricity exists in its positive state.[8] M. de Saussure[9] confirmed the observation of Le Monnier, that the electric condition of the air is subject to a tidal variation,

[1] Phil. Trans. 1759.

[2] See Libes,—Tr. Elementaire de Phys. iii. p. 276. Paris, 1801.

[3] Tentamen Theor. Elect. et Mag. 1759; Haüy,—Expos. Raisonnée, 1787. Robison,—Syst. Mechan. Philos. vol. iv.

[4] Phil. Trans.

[5] Mem. read at Roy. Inst. of Sc. Amsterdam; Annal. of Phil. xvi. 440.

[6] Ann. de Ch. et de Phys.

[7] Traité sur l'Elect. &c.

[8] Mem. Acad. Par. 1752. See also Mazeas,—Phil. Tr. 1753; Cavallo,—Ib. 1776, 1777.

[9] Voy. dans les Alpes. tom. iii. 306–315.

rising twice to the maximum, and falling as often to the minimum during twenty-four hours, these extremes depending much upon the hygrometric state of the atmosphere. He found that the electricity was generally strongest a few hours after sunrise and sunset, and weakest about two, before the rising and setting of that luminary,—the epochs of maximum and minimum diurnal temperature. He likewise observed, that the positive electricity of the atmosphere increased in proportion to the height at which it was collected, a fact reconcileable with the observations of Gay-Lussac and Biot on their aërial ascent, when they collected from the clouds, 160 feet below the balloon, by a wire and ball, *negative* electricity. Its amount and state are subject to great and rapid variations in cloudy weather. When the humidity of the atmosphere is beginning to manifest itself in the form of fogs, or other aqueous meteors, the electricity speedily assumes the opposite states, and makes frequent transitions. Black[1] ascertained, by numerous observations in the Mediterranean, that during winds of some duration blowing from the sea, the air is negatively charged, while it is positively electrified during winds coming from the land. Positive electricity gains its *annual* maximum during winter, and falls to the minimum in the opposite season, the observations being made during serene weather.

294. Schubler of Tubingen, between the years 1805 and 1811, made a series of interesting experiments on the electricity accompanying the condensation of aqueous vapour in the atmosphere, as affected by the direction of winds. During that period, the Professor made no fewer than 412 observations; the first series at Ellvanguen, in N. lat. 48° 57′ at an elevation of 1331 feet above the sea, between January 1805 and April 1806; and the second series at Stuttgard, in N. lat. 48° 46′, at an altitude of 847 feet, extending from June 1810 to August 1811. Among others, the following are the most important results:—*a.* By a north wind, the positive precipitations are slightly more frequent than the negative ones; and by a south wind, the negative ones are more than doubly

[1] Jour. in Mediter.

frequent. *b.* The ratio of negative precipitations by the south-east, south, and south-west winds; to those of the north-west, west, and north-east winds, is as 230 to 114. *c.* The ratio of negative precipitations by the N.W., W., and S.W. winds, to those of the S.E., E., and N.E. winds, is as 161 to 133. *d.* The ratio of *all* the precipitations is oftener negative than positive, as 155 to 100. *e.* The intensity of the electricity by the S.W., S., and S.E. winds, is weaker than that of the N.E., N., and N.W., as 39 to 75. *f.* The ratio of the intensity of the N.E., E., and S.E., is stronger than that of the S.W., W., and and N.W. winds, as 72 to 48. *g.* The mean intensity during *all* the precipitations observed in *all* the winds, is nearly the same as that of the electricity of the west wind precipitations. *h.* The greatest number of electrical precipitations takes place during west winds, and the least during east winds. *i.* The precipitations were observed to be commonly positive at the beginning, but were soon succeeded by negative ones of equal intensity ; that this often alternated, and at last ended in the form of negative electricity. From these data it follows, that the winds on the northern side of the windrose, have a maximum ratio of positive to negative electricity, while on the southern side of the compass the ratio is minimum.[1]

295. That lightning and electricity are *one*, is now firmly believed. The first suggestion of their identity is due to Stephen Gray,[2] a pensioner of the Charter House, and Fellow of the Royal Society. The electrical machine was then very imperfect, but he expressed the hope,—for by this time the germ was bursting,—" that there may be found out a way to collect a greater quantity of electric fire, and consequently to increase the force of that power, which by several of these experiments,

'Si parva licet componere magnis,'

seems to be of the same nature with thunder and lightning." Such a way was soon discovered, and with the leyden-jar, electricity was accumulated in large quantity. Still, however,

[1] Schubler,—Jahrbuch der Physik, 1829 ; Ed. Jour. of Sc. N.S. iii. 116.
[2] Phil. Trans.

the identity was hypothetical. Though Hawksbee and Wall had recognised the similarity, and although the Abbé Nollet, in 1746, had compared the thunder-cloud to the prime conductor of the machine, and Winkler of Leipsic had advanced some cogent arguments, still direct experiment was wanting for the proof. In 1752, Dalibard, distinguished as a botanist, had erected at Marly la Ville, in the vicinity of Paris, an iron rod forty feet high, and prepared for experiments upon atmospheric electricity. During a thunder-storm on the 10th of May, sparks were drawn from this rod, and a leyden-jar was charged! Dalibard was unfortunately absent at the time, but his place was supplied by Coiffier, assisted by M. Raulet, the village curate. Buffon performed the experiment in the capital, and it was repeated during the autumn at London with the same result. Long, however, before these iron rods were erected for this purpose, Bianchini informs us, that a pointed iron bar, placed in a vertical position in one of the bastions of Duino Castle, on the Adriatic, had been employed to warn of the approach of storms. Beside it an iron halbert lay, which the soldier on guard was wont to present to the metallic rod on the appearance of a change of weather. If he perceived sparks, or the semblance of a flame, the alarm-bell was sounded. Imperati refers to this ancient custom in the year 1602.

296. These early attempts to identify lightning and electricity were eclipsed by the better-conceived and ably executed experiments of Benjamin Franklin, in America. It was on the 15th of June 1752, in the afternoon, that Franklin and his son saw the hempen cord of their kite present an electric appearance. This kite was formed by two cedar rods crossing each other, and a silk handkerchief fastened by the corners to their ends. The rain which now descended in a torrent, conduced to the full effects which were expected. The wetted cord was rendered a conductor throughout its whole length, and from the suspended key, Franklin drew sparks in abundance on presenting his knuckle, and a leyden-jar was charged, —"arripuit fulmen cælo." So prone is the mind of man to reject truths which subvert preconceived opinions, that the

brilliant discoveries of Franklin were nearly doomed to suffer a temporary obscuration, like those of Copernicus, Galileo, Newton, and some even in our own day. What a galaxy of martyrs! The letters of the modest and perspicuous American were rejected for publication by the Royal Society of London! In England and France opposition arose—violent, puerile, and sickening. Truth triumphed over the Abbé Nollet and our countrymen. Priestley at home, and Beccaria in Italy, entered the lists and defended Franklin. The Royal Society elected him a Fellow, and, as if to atone for past faults, presented to him a medal! The Fellowship conferred upon him less honour than he did upon it; it may be forgotten, and the medal may moulder in darkness, but the name of Franklin will endure, and beam with greater radiance in ages yet unborn, in proportion as this subject is studied, and new truths are unveiled. The time is on the wing, when not only in India, but in Polynesia and Central Africa, the experiment of the electric kite will be familiarly known to every schoolboy, and the fame of Franklin wide as the world.

297. The following year, with a melancholy interest attached, Professor Richman of Russia verified the experiment. It was on the 6th of August 1753, when at a meeting of the Academy of Sciences of St Petersburgh, the sound of distant thunder fell upon his ear. Retiring, and taking with him Sokolow, they went to watch the effects which might occur. The Professor bent over his apparatus at the time when the imperial city was appalled by a tremendous peal. A globe of fire shot from the conductor to the head of Richman, and he fell lifeless to the ground![1] This leads us to refer to the melancholy fact, that deaths by lightning are of frequent occurrence. Taking the returns of mortality[2] at random, we find that in the years 1838, 1839, and 1840, there were killed in this way, in England and Wales, forty-six individuals. The largest number who died by lightning in one storm—that on the 18th of June 1839—was six; and on the *same* day of

[1] Ph. Trans. 1754, vol. xlviii. p. 765; Ib. 1755, vol. xlix. p. 61; Granville,—St Petersb. vol. ii.; Marbach's Enkyklopädie, Blitz; Taylor,—Med. Jurisprud. p. 568.
[2] Ann. Rep. Reg. Gen. London.

the preceding year, four perished in this way.[1] Such was the cause of the death of Leontius Pilatius, the friend of Boccacio and Petrarch, who, in the fourteenth century, was the first to deliver public lectures on Grecian literature in Europe.[2] During a thunder-storm in Gascoigne, in 1288, the lightning entered the chamber in which Edward I. and his queen were conversing upon a couch, passed betwixt them, doing them no injury, but killing two of their attendants![3]

298. Romas[4] in France, and MM. Becquerel and Breschet on the Great St Bernard, have performed, with slight alterations in the apparatus employed, the experiments of drawing electricity from the atmosphere. Mr Crosse of Bromfield, near Taunton, and Mr Weekes of Sandwich, have erected suitable means for collecting this fluid. By an ingenious adaptation of a modification of Volta's *eudiometer*, the latter has been able to shew through its agency the alternate, and almost momentary, analysis and synthesis of water.[5] Mr Crosse thus describes a scene which he witnessed during a thunder-storm, through the aid of his exploring wires:—"Some years ago," says he,[6] "with an exploring wire of only 1600 feet in length, I was gratified with a display of electric power during a tremendous thunder-storm, which continued between five and six hours such as I could scarcely have conceived. It took place in a warm summer evening. The giving and receiving balls were distant about one inch and a half from each other, when a strong explosion struck between them, on the approach of an enormous cloud. Shortly after, the discharge was repeated, until it became an uninterrupted stream of fire, apparently as thick as a goose-quill. Then succeeded a pause, and a change to the opposite electricity,[7] and again another pause, and a change to a still more intense state of opposite electricity. Streams of forked lightning were playing in all directions. I went out of doors to enjoy the sublime spectacle. The whole atmosphere seemed on fire, and at each pole,—at that time I

[1] Ann. Rep. Reg. Gen. London, 1841, p. 89.
[2] Berington,—Lit. Hist. Mid. Ages, book vi.
[3] Hol.—Chr. vol. iii. 284.
[4] Mem. des Savans Etrangers, tom. ii. et iv.
[5] Proceed. Elect. Soc. part i.
[6] Sidney,—Elect. p. 60.
[7] [Refer to note 2, at p. 116.]

had only three erected,—was a vivid stream of electricity passing between the metallic neck of the funnel used to protect the insulators and the top of the pole, as if the incessant stream of discharges within was insufficient to conduct away the fluid accumulated in the length of the wire. The thunder scarcely ceased for an instant from its rattling overhead, and the windows of the electrical room were thrown into such a state of vibration, that I expected every pane of glass to be broken. Now there was a moment's pause in the torrent of discharges, then again it was renewed with accumulated fury. Sometimes a steady, uninterrupted explosive stream took place; then succeeded short alternations of rest, and a burst of discharges, quite impossible to describe, attended with the most dazzling light. To have attempted an experiment at that time would have been certain destruction. The rain fell in torrents, and the whole scene far transcended philosophical or poetic power to describe."

299. The identity of atmospheric and machine electricity has been farther proved by the application of the former to electrolysis.[1] Water, as already stated, has been decomposed by its agency, and the late Mr Alexander Barry,[2] whose life has been sacrificed at the shrine of science, succeeded, in August 1824, in reducing a solution of sulphate of soda coloured blue by violets, to its acid and alkaline ingredients. He elevated the kite in an atmosphere favourable for the purpose. It was raised from an apparatus firmly fixed in the earth, and was insulated by a glass pillar. The usual shocks were felt on touching the string, which simple fact he mentions because no electrometer was employed to measure its intensity. The portion of string let out, with a double gilt thread passed through it, was 500 yards. He then made the connexion between the thread of the kite and one of the straight glass tubes which was filled with the solution mentioned, and with the other tube, which was similarly charged, made a connexion by a thread with the earth. These tubes were mutually connected, so that an electric current could pass between them. Hydrogen was soon observed bubbling

[1] *Electrolysis*, —ἠλεκτρον and λυω. I loose.

[2] Ph. Tr. 1831, pt. i. p. 165.

up in the tube to which the kite was attached, and oxygen in the other. In about ten minutes, the blue liquid in the former glass became green from the separation of the soda, while the liberated acid changed that of the other to a red. This experiment is conclusive, and very remarkable, for though such decompositions had been often accomplished before by voltaic electricity, common machine-electricity had failed to do so. Since then, chemical compounds have been frequently decomposed by Crosse and Weekes, by means of their operative media; and the latter gentleman has farther demonstrated the identity of these electric fluids by rendering iron powerfully magnetic, by placing steel bars longitudinally within a helix connected with the exploring wire of the apparatus.

300. Since the experimental proof of the unity of lightning and electricity, philosophers have pursued the inquiry still farther, with the view of identifying the latter with light and caloric. The discoveries of Oersted, Seebeck, and Faraday shew an intimate connexion. The last-named chemist has very recently announced another brilliant discovery which we shall merely enunciate,—that a ray of light may be electrified and magnetised, and that magnetic lines of force may be rendered luminous.[1] The experiments of Faraday have established "a true direct relation and dependence between light and the magnetic and electric forces; and thus a great addition made to the facts and considerations which tend to prove that all natural forces are tied together, and have *one common origin.*" It is through *diamagnetic* matter, *i.e.* through substances which transmit magnetic forces and polarized light simultaneously, that the effect is produced, and therefore we must not forget the possibility of changes on the molecular arrangement of the substance leading to the extraordinary result;[2] but to continue,—that "magnetic force acts upon the ray of light always with the same character of manner, and in the same direction, independent of the different varieties of substance, or their states of solid and

[1] Phil. Mag. 1845; Ib. 1846, vol. 28; Athen. No. 953, Jan. 31. 1846: Phil. Trans. 1846; Quart. Rev. clvii.; Silliman and Dana's Jour. May 1846. N. S. No. iii.

[2] Pouillet,—Mem. de l'Inst. No. 630.

liquid, or their specific rotative force, shews that the magnetic force and the light have a direct relation." It is foreign to our subject to pursue farther this new and delightful theme; we merely refer to it, believing that it is full of important results, affecting not only Meteorology, but the other sciences.

301. As the expansion of water in the act of freezing has been made available for the bursting of rocks, and the same property of wood when subjected to humidity, so the agency of atmospheric electricity has been directed to the same result. Thus in 1811, at Philipsthal in Eastern Prussia, an enormous block was shivered in a thunder-storm, by means of a tall iron rod duly provided for the purpose.[1] But it is only in isolated cases that lightning can be made subservient to engineering operations. Science has rendered us independent of such dangerous weapons, and given us agents of universal adaptation. The sea no longer presents an obstacle to submarine blasting, when the miner is armed with explosive materials and voltaic electricity; the mountain flies under the magic execution of gun-cotton,—the nitrate of lignine of Berzelius: thus, in March 1847, a pound of that substance rent and broke into nine pieces, a mass of close-grained quartz, whose solid contents equalled 220 cubic feet and weighed nearly fifteen tons. This was in the Standedge Tunnel of the Huddersfield and Manchester Railway, in the millstone grit of the Yorkshire hills.

302. Travellers, when on the summit of lofty mountains, are often enveloped in an atmosphere so charged with electricity that their bodies become highly electric. Saussure, Pictet, and Jallabert, while upon the Brevin in 1767, observed spontaneous flashes darting from their bodies, attended by a crackling sound. It was first perceived by M. Pictet, when pointing to the different mountains; a dark cloud was then in the middle region of Mont Blanc, directly opposite to their position. Saussure and Jallabert repeated the experiment and felt the same sensation in their fingers which their companion had described. All now stretched out their hands with

[1] Month. Mag. v. 22, p. 162.

a similar result. Jallabert heard a buzzing sound about his head, arising from a gold band upon his hat; he placed it upon the head of Pictet and Saussure, and they heard the same noise; even sparks were obtained from its golden button, and from a metallic ring around a large stick. It now thundered loudly, rain followed, and the storm passed without leaving a trace of electricity in the atmosphere. Another party, consisting of Mr Tupper, Mr Lanfiar, and guide, on Mount Etna, experienced similar electrical effects, on the 2d of June 1814, during a thunder-storm. They were descending, and near the *Casa Inglese* in the *regione deserta*, at the time when snow began to fall, with vivid lightnings attending. Mr Tupper felt his hair moving, and on raising his arm to his head heard a buzzing noise proceeding from his fingers; upon varying his motions, musical sounds were obtained, differing both in tone and intensity, and these were heard at a distance of forty feet. The other gentlemen and guide found that they too were electrified in the same manner. During a thunder-storm which occurred on the 15th of June 1825, while MM. Peytier and Hossard were upon the Peak d'Amie in the Pyrenees, elevated 8215 feet, they noticed their hair stand on end, and perceived a hissing noise issuing from the salient parts of their bodies. Sir William Hooker, and a party of botanists, witnessed the same effect upon Ben Nevis, on the 27th of June 1825. The hissing sound seemed to issue from stones which form the *cairn* upon the summit of the mountain; the hair of one of the party stood on end, as if he had seen "the angry spirit of the storm," and several other gentlemen, upon uncovering their heads, observed the same: the snow, soon after the appearance of which the phenomenon occurred, continued to fall thickly for two hours.[1] Professor Forbes of Edinburgh, when among the Alps, was on one occasion so near a thunder-cloud as to be highly electrified, and the angular rocks around him emitted a sound like that of the points near a powerful machine. Sir David Brewster bears testimony to the fact mentioned by M. Cavallo and Mr Nairne, of their having heard a crackling and sibilant

[1] Brewster's Jour. of Science, vol. iii. p. 312.

sound accompanying electricity in its passage from one place to another. Pike and his companions found the air so electric at Chihuahua in Mexico, that the blankets in which they slept gave numerous sparks upon being withdrawn.

303. When electricity passes from one cloud to another, oppositely electrified, or under-charged with the *same form* of electricity; or when the accumulated electricity of the clouds passes to the earth in what is termed the *descending*—in contradistinction to the *ascending—thunderbolt;* or in the latter case, directly from the earth upwards, we have the phenomenon of lightning, accompanied it may be, by thunder, which is merely the noise attending the change. Lightning may be classified into that which passes from cloud to cloud; that which descends upon the earth, and is occasionally forked; and that which rises from the ground, sometimes termed chain-lightning. The last ascends, says an accurate observer,—the Rev. Robert Moffat of Africa,[1]—"in figures of various shapes, crooked, zig-zag, oblique, and sometimes like a waterspout at sea; it continues several seconds, when the observer can distinctly see it dissolve in pieces like a broken chain." M. Arago,[2] divides this meteor into that which is zig-zag, and sharply defined, sometimes bifurcated, at other times dividing into three or more at the extremity; that which illuminates the cloud without exhibiting a definite form; and that which passes in balls. The last is alone of any duration. Sir William Snow Harris[3] attributes the formation of this peculiar ball-lightning to a constant succession of discharges while the cloud is in motion, bearing a strong resemblance to the *glow* of Professor Faraday. Lightning has been compared to the discharge from a leyden-jar, but more correctly it resembles the spark from the prime conductor of the machine, in which case it is *free* electricity.

304. Thunder, as shall be presently shewn, may be heard when no clouds are visible, but generally, and in this climate invariably, these vesicular bodies are present, reflecting the sound, and prolonging it by successive echos,—

[1] Southern Africa, ch. xx.

[2] Annuaire du Bur. des Long. pour 1838.

[3] Tr. on Thunder-Storms.

"The thunder rolls: be hush'd the prostrate world;
While cloud to cloud returns the solemn hymn;
Bleat out afresh ye hills, ye mossy rocks
Retain the sound."

THOMSON,—*Hymn*, v. 70.

Sir John Herschel supposes that the peculiar character of the noise may arise from the combination and quick succession of the sounds. The inconceivable velocity of lightning, accounts for the sudden disappearance of the flash, but the measured speed of sound, as it travels to the ear at the rate of 1123 feet per second,—the temperature being 62° F.,—explains the interval between the sight of the one and the perception of the other; and upon Sir John Herschel's theory, for the duration of the peal. The longest interval between the observation of the flash and perception of the sound, of which we are acquainted, was seventy-two seconds, mentioned by De l'Isle; this gives a distance of about fifteen miles. Hooke[1] thus explained the *rolling* thunder. The lightning being supposed to be moving in a direct line, the sound from the nearest point will first arrive, and should the flash be receding from the spectator, it will die away in the distance; should the lightning be directed obliquely, the roar will be similar, but more quick and full; but should it assume a circular course around the observer, the noise will reach his ear from every point at once, and a stunning crash be the effect; finally, should the electric-fluid pursue a zig-zag course, and be composed of broken curvilinear and rectilinear portions, the sound will be a combination of all the rest: when zig-zag alone, as Helvig observes, the sound may reach the ear, as often repeated as there are angles. There is an interesting observation recorded, which shews the influence of clouds in producing sounds like thunder. Colonel Beaufoy[2] and Sir Harry Mildmay were enveloped in a very dense cloud upon one of the Swiss mountains, when the fowling-piece of the latter gentleman went off, and the report was instantly followed by a rolling noise like thunder. The experiment was repeated with the same result; but when they got free of the cloud, and the

[1] Posthum. Works, p. 424.

[2] Ann. of Philos. vol. iv. p. 285.

atmosphere was restored to its wonted clearness, no roll succeeded its discharge.

305. Mountainous districts and the tropics are very frequently visited by thunder and lightning, and its effects are more terrific than in temperate regions. It rarely thunders, however, in Peru, although lightnings are seen among the Cordilleras. At Lima, Humboldt mentions that the records of thunder peals are preserved, *e.g.* July 13. 1652, at 8 P.M., in 1720, 1747, and on April 19. 1803. Though over oceanic surfaces, the equilibrium of atmospheric electricity is more stable than above the land, the presence of islands, as in the Pacific, exercises a powerful influence in producing changes in its tension, and this explains the frequency of electric storms there. The phenomenon is very rare in the polar regions.[1] In Europe, the "Infames Scopulos" of the Acroceraunian mountains, which Dion Cassius calls the Citadels of Thunder, are famous for their terrible storms of thunder and lightning.

306. The summer of 1846, so memorable in the annals of Europe, partook in its thunder-storms as it did in its temperature, the character of southern latitudes. Who can forget the storm of Saturday the 1st of August? Words fail to describe it; its violence was unprecedented. For some time before, the heat was intense,—the mercury in the shade ranging round 80° F., and in the sun rising to 120°; the air felt scorched, or like that at Palermo during the Sirocco. About 3 P.M. thunder growled over the metropolis, and very shortly after, burst like a terrific cannonade towards the northern counties of England. The attending phenomena were on a scale of awful grandeur, commensurate with the wide arena of their fury. The morning of that day,—the author describes from personal observations in Cheshire,—presented a striking contrast to that which preceded it. If the one was calm and lovely, the other had strange forebodings. Dense clouds spread over the sky, which the sun seemed struggling to pierce, but without success till noon; then he shone out in scorching heat. Towards the hour mentioned, threatening clouds were seen to

[1] Arago,—Ann. pour 1838, p. 388.

gather in the south, a few degrees across the meridian. Far in the distance there was a mass of leaden darkness; on both sides, but especially the S.S.E., cumuli were towering and rolling about in violent agitation. In the lower atmosphere, the stillness contrasted ominously with the troubled air above—it was soon to be disturbed. The clouds rolled from the south along the sky like waves of the ocean in a swell, pointing a jagged surface to the ground, like the carvings of a Gothic ceiling. On and on they rolled, till they reached the opposite horizon.

> "The sky is changed! and such a change!"

A rushing sound, like the noise of a distant cataract, was now heard, and it grew in force; the wind rose, and the branches waved. The animal creation seemed dismayed, seeking for shelter from an impending danger,—the fields were forsaken. Lightning now illuminated the unnatural gloom, the thunder peals were appalling, and rain and hail fell in a torrent. There seemed no end to the storm! It lasted in its fury nearly six hours.

> "Such sheets of fire, such bursts of horrid thunder,
> Such groans of roaring wind and rain, I never
> Remember to have heard."
>
> *King Lear*, act iii. sc. ii.

When the violence of the tempest abated, and the rains dried up, the distant lightnings were still of unparalleled grandeur, but now too far off to roll their thunders to the ear.

> "Where now 's the trifler? where the child of pride?
> These are the moments when the heart is tried!
> Nor lives the man, with conscience e'er so clear,
> But feels a solemn, reverential fear:
> Feels, too, a joy relieve his aching breast,
> When the spent storm hath howl'd itself to rest."
>
> BLOOMFIELD,—*Farmer's Boy.*

The darkness of night, deepened by a starless sky, had closed around, broken by the glare of frequent flashes. At these moments, the edges of the clouds stood out in bold relief, under their illuminating power. The forked lightning, and the effect produced, forcibly recalled the volcano. It was not

difficult to trace the likeness of molten lava in the clouds, which themselves resembled a mountain range in the horizon, starting up by enchantment, and glowing in a violet light. At length the storm was fully spent, and the morning air was refreshingly cold.

> "The day at last has broken. What a night
> Hath usher'd it! How beautiful in heaven!
> How hideous upon earth!
> And can the sun so rise,
> So bright, so rolling back the clouds into
> Vapours more lovely than the unclouded sky,
> With golden pinnacles, and snowy mountains,
> And billows purpler than the ocean's, making
> In heavèn a glorious mockery of the earth,
> So like, we almost deem it permanent;
> So fleeting, we can scarcely call it aught
> Beyond a vision, 'tis so transiently
> Scatter'd along the eternal vault."
>
> *Sardanapalus*, act v. sc. i.

Thunder-storms often extend simultaneously over a wide range of country. On the 11th of January 1815, a remarkable one took place in the Low countries and Westphalia; it stretched from Antwerp to Minden, or about 200 miles, and from Bonn to Nimeguen, or nearly 75 miles,—no fewer than twenty-four places were struck by lightning.[1] Upon the 3d of September 1841, one visited, at the same time, London, Paris, Rouen, Magney, Lille, Evereux, and other places in France; and when the May monsoon of 1848, burst upon India, a thunder-storm extended over a district of 600 miles from north to south, and measuring fifty miles in breadth:—an earthquake occurred at the same time, from Cambray to Simla.

307. A peculiarly lurid glare frequently accompanies a thunder-cloud, filling up the space between the cloud and the horizon. This is doubtless electrical, for it is met with where it cannot arise from the solar beams illuminating that portion of the sky with this unnatural brightness.

308. We have spoken of thunder unaccompanied by clouds. Let the following suffice for illustration. The phenomenon

[1] Benzenberg,—Gilb. Annalen. l. 341.

is described by Moffat[1] in Southern Africa, where it is denominated *serumairé* (*pron.* serumaeeree). "I have," says he, "frequently heard it during my long abode in the country, and once in a position where no clouds could be seen for fifty or sixty miles round, even on the most distant horizon, for many weeks; indeed, it may be said to be heard only when there are no clouds to be seen. When it does occur, which is not often, it is after the sun has passed the meridian, and when the day is hottest, with little or no wind. The explosion appears to be in the clear blue sky, and though over our heads, the intonations are soft, and nothing like lightning is to be seen." Volney mentions, that when at Pontchartrain, he heard four or five peals, but could not perceive a single cloud.

309. Although thunder and lightning in winter are rare, we have mentioned its occurrence during snow storms at that season. Holinshed[2] records the following instances in the 12th, 13th, and 16th centuries:—Nov. 1116, accompanied with hail; Dec. 1135, on the day Stephan of "Bullongne" landed; Nov. 1233; Dec. 1236; Nov. 1244; Dec. 1251; 1–12th Dec. 1563, a year memorable for the plague. In December 1710, there was a remarkable thunder-storm in Yorkshire.[3] Violent lightning and thunder with hail, occurred among the lakes of England, on the 3d December 1845.

310. The following very remarkable electrical phenomenon occurred in Java in the district of Cheribon, at midnight on the 11th August 1772. The mountain was seen to be enveloped in a cloud of unusual appearance, and at the same time loud reports like those of artillery were heard. The cloud rolled down the mountain side and overtook those who were unable to flee, enclosing them in its mantle, concealing the foot, and the ground for several miles around. It tossed about the terrified spectators like the waves of a troubled ocean, and emitted globes of fire, so vivid and so numerous that the darkness of night was dispelled by them. The effects were dreadful. For twenty miles, everything was laid deso-

[1] Mission. Lab. and Scenes in S. Africa, ch. 20.

[2] Chron. vol. iii. pp. 39, 46,—Matth. West; 217, 220, 236,—year 1242, West and Paris; 243, 1206.

[3] Thoresby,—Phil. Tr. No. 331, p. 320.

late,—houses overturned, plantations uprooted, 2140 human beings killed, 1500 head of cattle destroyed, besides horses, goats and other animals! Brydone[1] describes an extraordinary appearance, evidently of electric origin, which occurred in Malta on the 29th October 1767. "About three quarters of an hour after midnight, there appeared to the south-west of the city of Melita, a great black cloud, which as it approached changed its colour till at last it became like a flame of fire mixed with black smoke. A dreadful noise was heard on its approach, that alarmed the whole city. It passed over part of the port, and came first upon an English ship, which in an instant was torn to pieces, and nothing left but the hulk. The small boats and fellouques that fell in its way were all broken to pieces, and sunk. The noise increased and became more frightful. A sentinel terrified at its approach, ran into his box; both he and it were lifted up and carried into the sea where he perished. It then traversed a considerable part of the city, and laid in ruins almost everything that stood in its way. Several houses were laid level with the ground, and it did not leave a steeple in its passage. The bells of some of them, together with the spires, were carried to a considerable distance. The roofs of the churches were demolished and beat down, which if it had happened in the day-time must have had dreadful consequences, as every one would immediately have run to the churches. It went off at the N. E. point of the city and demolished the light-house, is said to have mounted up in the air with frightful noise, and passed over the sea to Sicily, where it tore up trees, and did other damage, but nothing considerable, as its fury had been mostly spent upon Malta. The number of killed amounted to nearly 200, and the loss of shipping, houses, and churches was very considerable." A singular electrical phenomenon was witnessed on the 8th January 1815, about 6 P.M., at Venice. The sky was overcast, and the thermometer only 2° above zero. Suddenly and silently a flame was seen to rise from the earth above the roofs of the houses, and spread over the church of

[1] Tour through Sicily and Malta.

Suffragio ; it lasted about four minutes, and was very vivid. Don Antonia Ulloa[1] witnessed a curious appearance of this kind at Quito, in South America. It was a globe of fire which seemed to rise from Mount Pickinka, about 9 P.M., and pass from west to south, till intercepted by another mountain. Its diameter was about a foot, and at first emitted an effulgent light so as to illuminate the part of the city opposite.

311. When lightning strikes many individuals closely connected, it would appear that those only at the extremities of the line sustain serious injury.[2] Thus, a stable at Rambouillet, in France, with a row of thirty-two horses, was struck by lightning on the 2d August 1785, and only the first was killed and the last wounded ; a school was struck in a similar manner at Knonaw, in Switzerland, near where Zwingle fell, on the 22d August 1808, and the first and fifth of a row of five children were killed, the others sustained merely a shock ; at Flavigny, Côte d'Or, where five horses in a stable were struck, the middle one suffered no injury ; of a chain of five horses, struck by lightning at a village in Franche Compté, the first and last were alone killed ; so at Praville near Chartres, in 1801, a miller walking between a horse and a mule was saved, while both animals perished. Colour does not appear to be without a certain influence, for, according to Arago,[3] of three recorded instances of animals struck by lightning, those parts of their bodies which were *white* alone had the hair destroyed.[4] On the 31st August 1826, while MM. Peytier and Hossard were on the peak of Baletous in the Pyrenees, 10,321 feet high, they had a *white* partridge struck by lightning.

312. The Ascending thunderbolt was first observed by the Marquis Maffei, about the beginning of the last century ;[5] since then the Abbé Lioni de Ceneda,[6] Richter,[7] and Seguier of Nismes have witnessed the phenomenon.[8] The following very remarkable case is recorded by John Williams, Esq.[9]

[1] Noticias Amer. vol. i. p. 41.
[2] Arago,—Ann. 1838.
[3] Arago,— Ann. 1838.
[4] Phil. Trans. lxvi. 493. 1776.
[5] Della formazione del fulmini.
[6] Jour. de Venise. tom. xxxii. art. 8.
[7] De natalibus fulm. tract. physicus, 1725.
[8] Vide Bertholon,—De l'Elect. des Meteores, tom. i. p. 132.
[9] Edin. Jour. of Sc. vol. x. p. 83.

It occurred upon the hills above Great Malvern on the 1st July 1826. A party had sheltered from the storm in a circular building roofed with sheet iron, and one of the ladies on entering the hut expressed her alarm lest the lightning should be attracted by the iron-roof. They had scarcely entered this retreat and were about to partake of some refreshment, when a violent storm of thunder and lightning came on from the west. About forty-five minutes past two, a gentleman who stood at the eastern entrance, saw a ball of fire which seemed to him moving on the surface of the ground. It instantly entered the hut, forcing him several paces forwards from the doorway. On his recovery from the shock, he found his sisters on the floor of the hut, fainting, as he imagined, from terror. Two of the ladies had died instantly; another lady and the rest of the party were much injured. The explosion which followed the flash of lightning was said by the inhabitants of the village to have been terrific. Mr Williams, who immediately examined the hut, found a large crack in the west side of the building, which passed upwards from near the ground to the frame of a small window, above which the iron roof was a little indented. Mr Williams conceived it to be quite clear, from the place of the fragment of stone and other appearances, that the clouds were negatively electrified during the storm.[1]

313. The Descending thunderbolt, or what is simply termed *the thunderbolt*, is of much more frequent occurrence, and is almost always accompanied with terrible effects. It occurs when lightning passes from the atmosphere to the earth. Against this electric rods or lightning-protectors are erected. Nothing can withstand its impetuosity; the oak which for centuries may have buffeted the storm, is shivered by its stroke and scattered to the winds, and buildings of the greatest strength offer no obstacle to its passage. A remarkable illustration of the effects of lightning occurred on the 13th of April 1832, near Tenbury, to Mr and Mrs Boddington of Badger Hall, while travelling.[2]

[1] Encyc. Brit. 7th ed. vol. viii. p. 619. See Lord Mahon,—Earl Stanhope,—Princip. of Elect.

[2] Faraday,—Phil. Mag.; Imper. Mag. vol. ii. 517.

314. This leads us to refer to the curious tubes called Fulgurites, or Fulminary tubes, met with in sandy districts, and supposed by Blumenbach to have originated in lightning, an opinion confirmed by Dr Fiedler from numerous facts in his possession, and the experiments of Hackett, Beudant, and Savart.[1] These fulgurites are silicious tubes of various sizes, vitrified internally; and when discovered *in situ*, pointing towards bodies which are good conductors of electricity. Fulgurites have been found in the Sahara; in the Isle of Amrum in Denmark,—Plaff; in other parts of Europe; and near to Drigg in Cumberland. In hillocks of drifted sand at the mouth of the Irt, three of these were found within an area of fifteen yards; the diameter of each was about 1.5 inches; one of them was traced to a depth of thirty feet without terminating, though it became smaller.[2] Analogous appearances have been observed by Ramond, Saussure, and Humboldt, upon the schists and porphyry rocks of the Alps, and in Mexico.

315. The Backstroke, or *return stroke*, is the flash which takes place at the farther extremity of the cloud, when the equilibrium is destroyed by a sudden discharge of electricity from the other end. It does not invariably occur, but when it does take place, it is highly destructive. A person may be killed by the backstroke, though many miles from the explosion. A phenomenon of this kind happened near Manchester;[3] but one of the most remarkable examples is that described by Mr Brydone,[4] which occurred at Coldstream on the 19th of July 1787, between 12 and 1 P.M., when a flash was seen, and thunder heard at an interval of half a minute, indicating a distance of about five miles. The observer was surprised with a loud and extraordinary noise, and was shortly informed that a man, Lauder, and a pair of horses, were killed close to him. On examination, there was found in the ground about four feet behind each wheel of the cart, a hole twenty inches in diameter, the centre of which corresponded with

[1] Ann. de Chim. Mar. 1828. tom. xxvii. 319.

[2] Trans. Geol. Soc. Lond. vol. ii.

[3] Nicholson's Manches. Memoirs.

[4] Brydone,—Phil. Tr. vol. lxxvii. p. 130.

that of each wheel, and the earth was torn up. There were indications of fusion on the iron-work of the cart, the left shaft of which was broken, and splinters thrown from its connexions with the metallic bolts. It was loaded with coals, and the deceased sat before. Not far off, a woman was thrown down, experiencing a violent blow on the foot; a neighbouring shepherd lost a lamb, and felt a glow over his face. The inference from the facts was, that the electric fluid had passed from the earth upwards through the cart. Upon the 29th of April 1833, what appears to have been a back stroke, occurred near to Edinburgh.[1] Between 3 and 4 P.M., a thunder-cloud was seen to form on the Kenleith hill, one of the north-west of the Pentland range. It directed its course towards the east, but about 5 o'clock suddenly advanced westward, and appeared to rest on the hill named. The cloud crossed the Water of Leith obliquely, near to Juniper Green; westward, the sky was clear, and the sun shone brightly at Currie. At that time there was a very vivid flash of forked lightning, followed almost instantaneously by an appalling peal like the rapid discharge of three pieces of artillery; the third crash was the most terrific, and it ceased as if instantly arrested. At this moment the attention of several persons was directed to the quarter whence the flash had appeared, when the ground was observed to be tossed up to the height of fifteen or twenty feet. On being carefully examined, many worms lying dead, soft and swollen, were noticed, and the ground was found to be excavated in the centre of the place to the depth of thirteen or fourteen inches. The zenith over this spot was at the time perfectly unclouded, and probably 300 yards from the margin of the thunder-cloud. The upheaving of the earth took place at the end of the last report. A man, distant 150 yards from the centre of the hole, to the eastward, was knocked down, and a woman removed as far to the southward of the same spot, was stunned.

316. Suggestions for safety. Sedulously avoid all conductors of electricity. Do not shelter under trees, nor come near them; the great majority of accidents arise from want of this

[1] Scotsman,—Let. from Mr Palmer to the Editor.

precaution. Do not handle, or be very close to metallic bodies, —a servant cleaning a silver fork at a window, during a thunder-storm, the prongs being outward, was struck, but not killed; a young lady during the same storm, sewing near a window, was thrown from her seat and experienced a glow. The centre of the room, if a metallic lustre is not pendant, is safer than any other part of the apartment. It is not safe to be between the window and door or fireplace, where there is a current of air. A bed is the securest retreat;—so all ye who fear, and fail to derive pleasure mingled with awe, in beholding this the grandest of nature's meteors, ensconce yourselves within the woollen folds, and, sunk in your downy couch, if ye cannot fall into gentle slumber, think at least that you enjoy comparative safety! M. Arago recommends that the bed should be suspended by silken cords, and instances the case of a female servant who was killed by lightning on September 27. 1819, at Confolens, Charente, while in bed; a gentleman asleep in bed at Harrowgate was killed by lightning on September 29. 1772, while his wife reposing by his side was not awakened.[1] An open field is a place of little danger; if the clothes are wet, the additional safety is a sufficient consideration,—but observe, do not let them dry upon your body. Every thing considered, it is safer to be indoors than out, during a thunder-storm: females and children, from statistical tables, enjoy greater impunity than males.[2] The danger is much increased by proximity to the storm. Of this fact it would be easy to furnish painful illustrations: we would, however, instance the following example, seeing the unfortunate sufferer was in the very centre of the storm,—we refer to the death of Buchwalder's assistant.[3] The tent which sheltered this engineer, was erected upon the summit of the Sentis, 7700 feet above the sea. Wind and rain, accompanied by cold, set in on the evening of the 4th July 1832, and before dawn snow began to fall thickly. About 6 A.M. of the 5th, it blew a tempest, with much thunder and light-

[1] Phil. Tr. vol. 63. [2] Arago,—Ann. pour 1839.

[3] Ergebnisse der trigonomet. Vermessungen in der Schweiz. p. 11.; Kämtz,—Met.; Murray's Handb. for Switz. 1842, p. 194, where he is named Buchmuller.

ning. They sought refuge in the tent, and both lay down together,—the terrific flashes and awful bellowings exciting fear in the mind of the servant. Scarcely was he quieted by the narrative of a similar storm which befell Biot and Arago in Spain, when a ball of fire appeared at his feet, and he cried, "Oh ! mon Dieu !" His face bore marks of the violence of the lightning, his chest heaved heavily and slowly, the right eye beamed with intelligence, but the other was a void—death settled on his countenance. Agonizing must have been the feelings of Buchwalder ! Alone, on the lofty pinnacle of Appenzell,—the elements unsubdued,—his companion called from his side in an instant to eternity,—himself injured and in danger ! With much difficulty he gained the nearest habitation, the hamlet of Alt St Johann.

317. This leads us to notice *en passant*, the safety secured to buildings by well-constructed protectors, and to vessels by the simple apparatus of Sir William Snow Harris.[1] Thus, by the latter, H. M. S. *Fisgard* was, on the 27th September 1846, struck by lightning off the Nisgually river, on the Oregon coast, and sustained no injury, although the vane-spindle was melted. The *Beagle*, protected in the same manner, was different times struck with impunity, once in the Rio de la Plata. The *Repulse* of 74 guns, not so protected, was crippled in the bay of Rosas; eight men were killed, and of nine hurt, several died. The same year—1801,—part of Sir J. B. Warren's fleet was disabled ; and in 1813, several vessels under Lord Exmouth suffered severely off Toulon. These were unprovided with the lightning conductors. From the want of such a protector, the powder magazine at Navarino was, in 1829, blown up during a thunder-storm, and above 200 soldiers suffered from the calamity. In 1764, the famous Castle of Heidelberg was reduced to what is now a picturesque and imposing ruin, through fire caused by lightning. Arago[2] gives many instances of similar disasters. The use of iron conductors appears to be of great antiquity, for Ctesias,[3] who

[1] Tr. on Thunder-st.; Naut. Mag.

[2] Annuaire 1838; Jameson's Jour. vol. xxvi. p. 122.

[3] Ctes. Indica. in app. Herodot. Wesseling ; Ann. of Philos. xx. 439.

joined Cyrus in the expedition against Artaxerxes, mentions that in India, iron fixed into the ground averts storms and lightnings.

318. In explaining the theory of clouds, it was observed, that electricity is evolved during evaporation, and we find that in those regions where the amount of this is the greatest, the air is most highly electric. Evaporation may be accounted the chief, but probably not the only mode, by which the atmosphere is charged with electricity. M. Pouillet[1] attributes the formation of a large portion of the electricity to the union of carbon and oxygen in the process of vegetation. According to M. Peltier,[2] it is due to the constant negatively electric condition of our globe. De la Rive[3] assigns its origin to the unequal distribution of caloric in the atmosphere; and Herr Reiss, to the friction of vaporous particles, in support of which view the phenomena of the electricity of steam may be cited. Count Volta has shewn that bodies while assuming the gaseous form absorb electricity, which they again emit in its positive state on being condensed.

319. There is an electric phenomenon of peculiar character, termed Sheet or Summer-lightning,—*Eclairs de chaleur,*—unaccompanied by thunder, or too distant to be heard. When it appears, the whole sky, but particularly the horizon, is suddenly illuminated with a flickering flash. Matteucci supposes that it is produced either during evaporation, or evolved, —according to Pouillet's theory—in the process of vegetation, or generated by chemical action in the great laboratory of nature, the earth, and accumulated in the lower strata of the air in consequence of the ground's being then an imperfect conductor. Arago and Kämtz have adopted a very different view of the nature of these lightnings, considering them as reflexions of distant thunder-storms; and the author has often observed thunder-storms preceded and followed by this phenomenon. We have seen the cumulo-stratus cloud in the horizon, start into view during the play of summer-lightning.

[1] Ann. de Ch. et de Phys. 1827. xxxv. 405: Elm. de Phys.

[2] Compt. Rend. de l'Acad. des Sc. xii. 307; Becquerel,—Tr. de l'Elect. iv. 107.

[3] Essai Hist. sur. l'Elect. p. 140.

Saussure[1] informs us, that he observed sheet-lightnings in the direction of Geneva, from the Hospice du Grimsel, on the 10–11th July 1783, while at the same time, a terrific thunder-storm raged at Geneva. Howard[2] mentions, that from Tottenham, near London, on July 31. 1813, he saw sheet-lightnings toward the S.E. while the sky was bespangled with stars, not a cloud floating in the air; at the same time a thunder-storm raged at Hastings, and in France, from Calais to Dunkirk. Arago instances the following illustration in support of his opinion, that this phenomenon is reflected lightning ;—in 1803, when observations were being made for determining longitude, M. de Zach on the Brocken, used a few ounces of gunpowder as a signal, the flash of which was visible from the Klenlenberg, sixty leagues off, though these mountains are invisible from each other.

320. St Elmo's Fire.—This meteor is the *Castor and Pollux* of the ancients, sometimes called Tyndaridæ ; it is the *Corpo-Santo* of the Portuguese, hence the *compasant* of sailors ; the Fires of St Peter and St Nicholas of the Italians ; the St Clare and St Helene of the French ; and the *Tree Vuuren* of the Dutch. It is an electrical meteor of great beauty, sometimes seen on land, but more frequently at sea during storms, appearing as a brilliant light resting upon the masts. The origin of the name and the earliest memorial of the phenomenon, is associated with the famous Argonautic expedition to Colchis, when, during a storm, two lambent flames settled upon the heads of Leda's sons : the era of this expedition is about 1260 years before Christ. This meteor was studied by the Greeks and Romans in their divinations. Of all the omens, the *ignis lambens* was accounted one of the most felicitous, especially when more than one appeared. Theocritus[3], Euripides[4], and Horace[5] celebrate it in their verses. The records of hore antiquity are not wanting in its examples. Plutarch[6] mentions it in the Life of Lysander. Pliny[7] observes, that it settles not only upon ships, but upon the human head. Cæsar[8]

[1] Voy. dans les Alpes. [2] Met. Observ. [3] Dioscuri.
[4] Orestes. [5] Carm. lib. i. Ode 12. [6] Plut. Lives, fol. 1579, pp. 222, 452.
[7] Nat. Hist. book ii. [8] Comment. de Bello Afric. cap. vi.

instances its appearance after a storm of hail, upon the points of the spears of the fifth legion,—"Perid tempus fere Cæsaris exercitui res accidit incredibilis auditu, nempe vigiliarum signo confecto, circiter vigilia secunda noctis nimbus cum saxea grandine subito est coortus ingens; *eadem nocte legionis quintæ cacumina sua sponte arserunt.*" Seneca[1] observes, that it settled on the spear of Gylippus as he was going to Syracuse. Livy states, that it was seen upon the spears of some soldiers in Sicily, and also that the shores were luminous. Procopius[2] says, that in the war against the Vandals, Belisarius was favoured by the same auspicious omen. The same meteor is mentioned in the records of the second voyage of Columbus,[3] when, during a storm in Oct. 1493, seven were seen upon the masts. The sailors inheriting the superstitious fears of the ancients, began to chaunt thanksgivings for their appearance, thinking them a happy omen of deliverance from the tempest. In the memoirs of the Count de Forbin, it is recorded to have been seen in 1696, during a thunder-storm among the Balearic Islands. "We saw," says the Count, "more than thirty St Elmo's Fires. There was one playing upon the vane of the mainmast more than a foot and a half high. I sent a man to bring it down. When he was aloft, he cried out that it made a noise like wetted gunpowder in burning. I told him to take off the vane and come down; but scarcely had he removed it from its place when the fire quitted it, and reappeared at the end of the mast without any possibility of removing. It remained for a long time, and gradually went out."

321. Lord Napier thus describes an appearance of the St Elmo's Fire in the Mediterranean in June 1818:—"About nine, when the ship was becalmed, the darkness became intense, and was rendered still more sensible by the yellow fire that gleamed upon the horizon to the south, and associated by the deep-toned thunder which rolled at intervals in the mountains, accompanied by repeated flashes of that forked lightning whose eccentric course and dire effects set all de-

[1] Quæstiones Nat. lib. cap. 1. [2] Hist. Justin,—Bell. Vandalorum, lib. ii. cap. 2.
[3] Hist del Almirante.

scription at defiance. By half-past nine, the hands were got aloft to furl the topsails, in preparation for the threatening storm. When retiring to rest, a sudden cry of St Elme and St Anne was heard from those aloft, and fore and aft the deck. On observing the appearance of the masts, the main-top-gallant masthead, from the truck for three feet downwards, was completely enveloped in a blaze of pale phosphorescent light flitting and creeping round the surface of the mast. The fore and mizen top-gallant mastheads exhibited a similar appearance. This lambent flame preserved its intensity for the space of eight or ten minutes, and then it gradually became fainter till it diminished at the end of half-an-hour." Captain Clavering,[1] of the Griper, witnessed this electrical phenomenon during a severe gale, on the 6th Dec. 1823, when a hundred miles west of the Fiord of Drontheim. It assumed the form of *balls* of fire at the yard-arms and mast-heads, eight of which were counted at once. On the 9th of March 1835, at midnight, seven of these meteors were seen at the masts and cross-trees of the *Royal William* steam-ship, upon her passage from London to Leith, during a storm of sleet and wind from the N.W.; it lasted an hour, and was observed by the seamen who ascended the masts, to hiss like heated iron plunged in water. In September 1827, a fine appearance of this phenomenon, seen off the coast of Brazil, was communicated by Lieutenant Milne, R.N. to Professor Jameson. Mr W. Traill of Orkney, mentions having seen this meteor there, during a heavy gale, in February 1837. The whole mast, he observes, was illuminated, and from the iron spike at the summit, a flame twelve inches long pointed to the N.N.W., from which a dense cloud was rapidly advancing. The cloud approached, accompanied by thunder and hail; the flame increased, following the course of the cloud till the latter was immediately above, then its length was nearly three feet; after this it rapidly diminished, pointing, however, to the cloud which was borne rapidly to the S.S.E. This fine appearance lasted about four minutes.[2]

[1] Sabine,—Pendulum Exper. p. 181.

[2] See Todd's Works,—Student's Manual, ch. i., where there is a fine description of a storm at sea, when this meteor appeared. This book should be in the hand of the student for frequent perusal.

322. In January 1822, the trees on the road to Freyberg, during a falling snow, were seen by M. de Thielaw to be faintly luminous. M. Maxadorf in January 1824, observed, near to Cothen, a cart of straw under a dark cloud, the ends of the straws and the carter's whip being distinctly phosphorescent. In August 1768, Lichtenberg saw the St Elmo's Fire in the spire of St Jacques at Göttingen; and in January 1778, during a storm, Mongez observed the same meteor on some of the elevated summits of the city of Rouen. Captain Bourdet observed it in December 1806, in Poland, upon the ears of the horses, the metallic ends of the harness, and the whiskers of the troops; the phenomenon continued during a gust of wind, and on its disappearing, there fell a heavy shower.[1] Dr Guyau[2] mentions, that this meteor is frequently seen upon the bayonets of the soldiery at Fort Gowraya, Bougie, situated on the summit of Mount Gowraya, 2200 above the sea. On the 8th of May 1831, Rozet[3] mentions, that when some officers were walking after sunset, on the terrace of the Babazounat, Algiers, being uncovered, they saw the hair of each other's heads standing on end, tipped with minute luminous tufts, and on elevating their hands the same appearance was visible at the points of their fingers. Saussure and Kämtz mention having seen this meteor on the Alps. To it, Virgil alludes in these well-known lines: —

"Ecce! levis summo de vertice visus Iuli
Fundere lumen apex, tactuque innoxia molles
Lambere flamma comas, et circum tempora pasci."
Æn. ii. 682.

"Strange to relate! from young Iülus' head
A lambent flame arose, which gently spread
Around his brows, and on his temples fed."
DRYDEN'S *Translation,—Æn.* ii. v. 930.

[1] Ed. Phil. Jour. xi. 404.
[2] Recueil des Mém. de Méd. Militaire, t. xxxix.
[3] Voy. dans la Rég. d'Alger.

CHAPTER XIII.

"The time will come when the most profound secrets of nature shall be unveiled, and when posterity shall be astonished that so simple explanations of grand phenomena should for so long have been concealed."—SENECA.

323. The Bolis or Fire-ball is a luminous meteor of much splendour, moving with considerable velocity at various altitudes, and frequently of great magnitude. The meteor is generally accompanied by a tail, and disappears in scintillations, attended sometimes with an explosion, occasionally leaving a luminous track behind, after it has become invisible. Baron Humboldt[1] tells us of the mythological associations of the Lithuanians with this meteor, who suppose that the Verpeja began to spin the thread of the infant's destiny at its nativity, attaching an end to a star, which was cut at death, the star falling to the earth and being extinguished. The Mohamedans,[2] however, attach to it a different import. The

[1] Cosmos, vol. i. p. 378; Grimm's Deutsche Mythologie, 1843, 685. [2] Fryer.

fire-ball and shooting-star, according to their ideas, are fire-brands, hurled by the good spirits from their heathen paradise against the bad, when the latter approach too near their sacred precincts:—

> "The starry brands
> Flung at night—
> At those dark and daring sprites
> Who would climb the 'empyreal heights."
>
> MOORE,—*Lallah Rookh.*

324. Fire-balls occasionally accompany meteoric stones in their descent; nevertheless, these phenomena must be considered independent, for the bolis may appear without the meteorolite, and *vice versa.* Various theories have been proposed to account for them, but that which seems to be most tenable assigns their origin to electric agency. Halley[1] conjectured an origin remote from our earth, for, referring to the Bononian meteor of 1676, he observes, that he was "induced to think that it must be some collection of matter formed in the ether, as it were by some fortuitous concourse of atoms, and that the earth met with it as it past along in its orbit."

325. Kepler[2] mentions a fire-ball which was visible over Germany in the year 1623. Montanari[1] in 1676, saw a bolis at an altitude of thirty-eight miles, in Italy, which crossed from Dalmatia and made for Corsica; before bursting, it seemed to be twice the size of our satellite, and a hissing sound was audible. From the fact, that when this meteor exploded, and its fragments fell into the sea, there was a noise like that produced when heated iron is plunged into water, it is conjectured that this bolis attended the fall of a meteoric mass. Halley[3] and Gottfried Kirch[4] make mention of a large bolis seen in July 1686. Cotes describes a luminous meteor of this kind which was visible in England on March 6. 1716 , and Halley[5] mentions another, which appeared in 1719. The altitude of the latter was estimated at 70 miles; its velocity at about 350 miles per minute; and its diameter upwards of a mile and

[1] Phil. Tr. No. 341, Motte's Abr. v. ii. p. 139. [2] Kepler,—Ephemerides.
[3] Phil. Trans. vol. xxix. p. 161; Abr. ii. 140.
[4] Ephemer. 1688, Append. [5] Phil. Trans. No. 360, p. 978.

a half: the sound of its explosion was heard over Britain. Priestley takes notice of a fire-ball, said to have been "as large as a millstone," which was seen at sea, in lat. 42° 48′, and W. long. 9° 3′, from the *Montague*, on the 4th November 1749; it broke with a violent crash, the main-top-mast being at the same moment shattered, and a strong sulphureous smell perceived; five seamen were thrown down, and one much hurt. We are disposed to class this meteor, which was seen rolling upon the sea like a large blue ball, with ascending thunderbolts, rather than with fire-balls. On the 26th of November 1758, a bolis appeared in this country, moving with the velocity of 30 miles a second; its altitude at Fort-William was estimated at 30 miles, and at Cambridge at 95: it is described by Sir John Pringle. Le Roi witnessed one in July 1771, the diameter of which was about 1000 feet.

The most remarkable bolis in record is that described by Blagden.[1] It occurred on the 18th August 1783, about 9 P. M., and was visible over a wide extent of Europe, from the north of Ireland to Rome, frequently changing its form and hue. It crossed the zenith at Edinburgh, and then appeared round and well defined, of a greenish colour, casting a shade upon the ground of a similar tint; a tail of considerable length attended it. Its aspect was much changed when seen at Greenwich, for it then looked like two bright balls, the diameter of which was about two feet, followed by others connected together by a luminous body, and finally terminating in a blaze tapering to a point; the colours of the balls were different. This was a phenomenon awfully grand! The height of the bolis was estimated to be far above that usually assigned to our atmosphere, its speed was not less than 1000 miles a minute, and its diameter was computed at 2800 yards. Cavallo[2] describes this meteor as seen at Windsor, when its explosion was heard like a peal of thunder, ten minutes after its rupture was observed. Another meteor, but not so fine as the last, was seen on the 4th of October in the same year, the altitude of which was estimated at 50 miles, its diameter nearly 200 yards, and velocity about 700 miles a minute.

[1] Ph. Tr. vol. lxxiv., 1784.
[2] Ib. 1783, p. 435.

Humboldt mentions a fine meteor seen at Popayan, in N. lat. 2° 26′, in 1788, at noon.

326. On the 18th November 1803, about 8.5 P.M., a brilliant meteor appeared at London, rendering legible the writings on the sign-boards. In 1808, one was seen in Greenland, where such phenomena are rare, moving from N.W. to S.E. A beautiful fire-ball, which Pictet[1] has described, was seen in 1811. On the 2d December 1814, a remarkable meteor was witnessed near London about 10^h 40^m P.M., having a brilliancy equal to the light of day;[2] and on the 29th of September 1814, about 8 o'clock, another was seen at the same place, moving from N.E. to N.[3] One having an apparent semi-diameter of the moon, white at first, but before its extinction, bright blue, tinged with red, was seen, on the 6th October 1817, at Tunbridge Wells by Mr Forster.[4]

On the 23d of March 1816, about 11 P.M., a large bolis was seen at Oxford, Lambourn, in Berks, and at Egham, in Surrey, crossing the sky from south to north, and followed by a rumbling noise like thunder, which continued for about five minutes. Two very brilliant fire-balls appeared in 1817.

Upon the 6th of February 1818, one which has been described by Dr E. D. Clarke,[5] descended vertically from the northern part of the hemisphere about 2 P.M.; its light was so intense, that it shone with an effulgence equal to the sun which was then shining in a cloudless sky. Dr Clarke supposes that a meteoric body fell from this meteor, and accounts from Lincolnshire state, that upon the appearance of this fire-ball a hissing sound was heard, and a trembling of the earth took place like the shock of an earthquake. Mr Howard[6] mentions one which passed from S.W. to W. on the 1st August 1819, and was seen at Tottenham. Several luminous meteors appeared on the 17th October, same year, during the play of the aurora borealis;[7] and on the 18th November, same year, another was seen at Tottenham. Upon the 21st November

[1] Biblioth. Britan. May 1811.
[2] Ann. of Philos. vol. v. p. 236.
[3] Ib. vol. vi. p. 320, 465.
[4] Ib. vol. x. p. 320.
[5] Ann. Phil. xi. 273; Norwich Merc. Feb. 14, &c.
[6] Ann. Phil. xiv. 320.
[7] Ann. Phil. xiv. 395,—Dr Burney, Gosport Observatory.

1819, one the *actual* diameter of which appeared to be nearly half a mile, was seen at Danvers, Massachussets, Baltimore and Maryland. Its direction was nearly S. 44° W., and its height from trignometrical measurement, was computed at 38 miles on its appearance, and 22 when it was lost to sight; two minutes after its disappearance, a rumbling noise was heard for upwards of 90 seconds.[1] Several appeared that year in Cutch, at the time of the earthquake. On the 29th of November 1820, a luminous meteor was seen at Cosenza, in Italy. Three are recorded in the following year by Mr Bennet:[2] —one of them occurred in July, during a thunder-storm, which was as big as a man's head, and fell into the ocean near the ship: the second was on the 7th September, it had a red colour, and passed from E. to W., disappearing in the offing, "with the glowing hue of intensely heated iron;" the sky, which was serene at the time, became cloudy and heavy rains began to fall: the third appeared on the 18th of the same month, having an apparent diameter equal to the moon, and an easterly course from the zenith; it burst and fell with great velocity among the waves. On the 28th October 1822, about 5.5 P.M., a fine bolis was seen about 50 miles south of London, by Mr Davenport.[3] Fire-balls were seen in 1823, at Gosport, on the 26th of January; at Kiel in Denmark, on the 23d of May; at Ragusa, on the 20th of August, which was contemporaneous with an earthquake at the same place; and on the 13th of the same month, by Hansteen,—it is curious that the last of these meteors was seen to cross the field of his telescope, at 11.25 A.M., while he was making an astronomical observation.

Upon the 2d of January 1825, about 2 A.M., a curious luminous meteor was seen by M. Antonio Brucalassi, on his return to Arezzo, between S. Giovanni and Montevarche: it appeared suddenly about ten fathoms from the ground, and apparently not far off, in the form of a truncated cone. It seemed a mass of fire, which by its rapid motion left a track of light that gave it the shape described; sparks of great brilliancy were

[1] Bowditch,—Mem. Amer. Acad.; Ed. Phil. Jour. vol. vi. p. 380.
[2] Voy. and Trav. vol. i. pp. 23, 46, 54.
[3] Ann. Phil. xxi. 235.

given off as it moved from W. to E. with a rapid motion. The entire length of the meteor appeared to be two fathoms, and its diameter at the base half a fathom ; during its continuance it shed a most effulgent light. The sky was clear at the time, the atmosphere was calm and cold, and both before and after this meteor, many shooting stars were witnessed.[1]

On the 3d of November 1826, a little after sunset, one was seen by Colonel Blacker, near Calcutta ; it had nearly the moon's semi-diameter, passed from S. to W., and disappeared in sparks. A meteor of great brilliancy was seen during sunshine, on the 21st November 1828, both at Edinburgh and Doncaster ; from the relative positions of these places and its direction, this bolis must have occupied a position at the time vertical near to Dublin, at an altitude of about 60 miles, and with a diameter of 1320 yards. Some years later, a very brilliant fire-ball crossed the sky at Edinburgh about 3 P.M. Mr B. D. Silliman witnessed a fire-ball shooting across the sky in the direction of N.E., from about five below the zenith. On the 11th February 1828, about midnight, while sailing between New York and Long Island, it was of a fine grass-green colour, and the tail and scintillations were of the same hue.[2] A very remarkable bolis was seen by many observers over a wide extent, on the 29th June 1832, near to midnight,—characterised by slow motion, great brilliancy, and variety of form and colour. Its light was compared to that of the oxy-hydrogen flame ; at one time it resembled an egg of brilliant blue, with a luminous tail which it soon lost ; at another, it became of a vivid white, and, expanding to a ball of about four feet diameter, changed to red.[3] Dr Traill[4] of Edinburgh, mentions having witnessed a similar meteor at sea, on September 18. 1835, at 8 P.M ; the head was elliptical, of a most intensely brilliant bluish-white light ; the tail had a tint of azure mixed with red from which sparks proceeded. Its motion was nearly horizontal from S.W. to N.E., disappearing in a dense cloud, after having been seen about six seconds ; it was thought to emit a crackling sound. On the 13th of November

[1] Antòlogia, Feb. 1825; Ann. of Philos. xxviii. 75. [2] Silliman's Amer. Jour.
[3] Phil. Mag. [4] Phys. Geog.

1835, a barn near Belley, in the Département de l'Ain, was fired by a bolis. On September 21. 1837, at 7^h 48^m P.M., one which cast a shadow was seen at Paris; and on the 17th March 1838, another was seen at Kensington.[1] Upon the 21st December 1841, a bolis, twice the apparent diameter of the moon and exceedingly effulgent, appeared in Scotland; the tail was variegated and the body burst in a blaze of light,—it was seen at Glasgow and near to Stirling at the same time. On the 5th February 1843, about 8 P.M., a bolis passed over Notts, resembling a large mass of fire, of a blood-red hue, and assuming various shapes; its course was from N.W., its apparent height trifling, and its velocity about fifty-five miles per minute.[2] On the 20th July 1844, a great meteor appeared at Parma and Nuremberg;[3] and on the 27th of the same month, one was seen at Brussels.[4] On the 24th April 1845, about 9.5 P.M., a large bolis of a blue colour was seen in this country; it burst in *Leo Major*, but without a train.[5] On the 16th July same year, another luminous meteor is recorded;[6] and in the following month, a large bolis was seen at London.[7] On June 20. 1846, about 8.5 P.M., a bolis was witnessed at Marieux near Autun, Saone et Loire; it was of a violet colour, and seemed a yard in circumference. It continued visible about a minute, and descended perpendicularly to the horizon, giving off five other balls, each nearly one-fourth the size of the parent mass, which nevertheless preserved its original volume; before disappearing it burst into sparks spreading far and wide.[8] Upon the 1st August same year, about 10.5 P.M., at Cassel, a fire-ball was seen at an altitude of about 80°, near to the meridian; it burst with a sibilant sound, leaving behind a train of sparks.[9] The same meteor, in form of a luminous horizontal bar, was witnessed at Gross Krotzenberg. A bolis appearing as large as an orange, with a train some yards in length, crossed Wrenbury, Cheshire, on the 15th September 1846, about 10 P.M.; and a most magnificent fire-ball, lurid but effulgent, was seen

[1] Phil. Mag. [2] Not. Jour. [3] Bull. Acad. Brux. xi. 29.
[4] Ib.; Brit. Assoc. Rep. 1847,—Powell's Catalogue.
[5] Lond. News. May 3. 1845,—Diag. [6] Professor Powell's Catal. [7] Ib.
[8] Even. Mail. [9] Ib.

at London on the 25th. On Oct. 17. 1847, at 6.5 P.M., a very fine bolis was observed by my friend the Rev. Charles Aldis, crossing from S.W. to N.E., at Wrenbury, with a long train and a faint whizzing noise; another of very large diameter, was seen near to midnight on the 23d November of the same year, at Birkenhead. The finest bolis which the author ever witnessed, occurred on the 2d February 1848, about 9 P.M. The night was calm and beautiful,—three hours before he had been testing a reflecting telescope upon the ring of Saturn. Returning from a professional visit, his attention was drawn to the south, by a sudden and brilliant light not far from Orion. It was a fire-ball slowly descending at an angle of nearly 20°. Its light was more intense than that of Jupiter, which was then shining in great splendour, and it had a decided apparent diameter. The body of the meteor was coloured grass-green, and it was partially bordered with crimson, in a crescentic form, in the direction of the white and tapering tail. The bolis disappeared without sparks, falling seemingly to the ground, between the observer and the wood of Combermere Abbey, nearly a mile off. Before sunrise, the sky was overcast; the following day was bleak and windy, and rain soon followed. Upon the 8th of March same year, a luminous meteor shot across the clouded sky at Bath, from the south-west; the nucleus seemed larger than a cricket-ball, and the tail appeared about three quarters of a yard in length.

327. On the 4th of October 1842, at midnight, a very remarkable meteor, similar in most respects to the bolis, was seen from Cambridge Observatory. The sky was clear and the air frosty, when at 21 minutes after 12, a vivid light drew the observer's attention to the constellation Orion. It was a luminous streak 20° in length, in the centre of which was a spot, bright as the planet Jupiter, which appeared to be the focus of the effulgence. The light flickered on either side simultaneously, and with every wave it decreased in brightness and in length, till it declined altogether, leaving the brilliant star-like point in its original position. These changes lasted 10″; then the light gradually faded, and in two minutes entirely disappeared. The central light was in a

line with the three stars of Orion's belt, and 3° to the north; the inclination of the luminous streak was 40° to the S.E. of the belt. What was the nature of this phenomenon? Was it a fire-ball, the path of which was in a straight line with the observer, neither deviating to the right nor to the left a hair's breadth; or was it an electric meteor fixed in its original position by a law of which we are still ignorant? Perhaps the Siderial astronomer may tell us if it was a body of which the noblest, the most perfect, and most sublime of all the sciences, takes knowledge. It reminds us of the star which burst forth in the time of Hipparchus, or that which appeared about two centuries and a half later, blazing for a time and becoming extinguished.

328. Meteorolites, meteorites, aërolites, and stones which have fallen from the sky, are terms expressive of the same phenomenon. Although the statements of the ancients, and even some in modern times, have been doubted, it is beyond suspicion that such bodies have actually reached our earth. The British Museum is rich in them, and Partsch[1] has published an account of 258 specimens in the Vienna Cabinet. Although their descent is generally announced by the explosion of a fire-ball and by a rushing sound, they have been found to fall from a small black cloud in a tranquil sky, unaccompanied by any luminous meteor.

329. In the historical record of these phenomena we shall avail ourselves chiefly of the Catalogue of Chladni, dividing the occurrences into epochs, anterior and posterior to the birth of Christ, beginning with those which fell before the Christian era[2] Fable sings of the fall of stones upon the enemies of Hercules by Jupiter; and we are told by the Arabs that when their sacred city was besieged by the profane Ethiopians, a similar disaster befell them. Amongst the ancients, Isidorus, Eusebius, Appian, Herodian,[3] Æschylus, Pindar, Pausanius, Ammianus Marcellinus, Dion Cassius, Virgil, Tibullus,

[1] Die Meteoriten. Vien. 1843, pp. 162.

[2] We gladly acknowledge the following sources of information:—Chladni, —Ed. Phil. Jour. vol. i. 1819; Edin. Encyc. *art.* Meteorite; Ann. of Philos. vol. xxviii. 1826; Annales de Chimie.

[3] The Elagabalas at Emisa, in Syria, taken to Rome; lib. v.

Valerius Maximus, and others, notice the phenomenon. Pliny mentions stones preserved at Abydos and Cassandria, but the date of their descent has been lost. Uncertainty hangs over the epoch of the famous meteorolites, "the mother of the gods,"[1] and the "Black stone" preserved in the Caaba of Mecca. The latter is held in great veneration by the Mahomedans. It occupies the south-east corner of the Caaba, and is raised about forty inches from the ground; it is built into the wall and is incased with silver. There is a tradition that it came from heaven, and the Moslems call it *Hajra el Assouad* or Heavenly stone. In shape it is an irregular oval, about seven inches in diameter; its colour is dark brown, but is said to have been white. Its surface is uneven, and composed of irregular pieces which have been cemented. In the year 682 it was split into three fragments by fire, but was again united. Being an object of such adoration, it was carried off in triumph by the Carmathians when they plundered the Caaba, but not till it had been again fractured. After being in their possession for twenty-two years, they restored it to its present place, where it receives the kisses of the faithful.

Malchus mentions a "thunder-stone" which fell in Crete, in 1478 A. C., and it is recorded in the Parian Chronicle.[2] Pausanias notices stones kept at Orchomenos, in the year 1200. The *ancyle* or sacred shield which fell in the time of Numa Pompilius,[3] about 700 years before Christ, was most probably a meteorolite. We need scarcely say that the veneration of the Romans for this body was such, that Numa

[1] This stone was preserved in a temple at Pessinus in Phrygia, and supposed to be the statue of the goddess Cybele, hence called Pessinuntia. It was taken to Rome during the second Punic War. See Strabo xii.; Pausan. vii. cap. 17; Liv. xxix. 11. 14.

[2] l. 18, 19. The Parian or Aurundelian Marbles contain chronology during years 1582—355 A. C. The characters are Greek, and were executed 264 years before Christ. Two translations appeared by Selden in 1628, and Prideaux in 1676, and copies by Mattaire in 1732, and Chandler in 1763. These ancient marbles, discovered in 1610 at the Isle of Paros, were given to Oxford University by Lord Arundel in 1627. They consist of 37 statues, 128 busts, and 250 inscriptions. See Kidd,—Tracts; Robertson, 1788; Porson,—Mon. Rev. Jan. 1789; Hewlett,—Archæology, vol. ix.; Encyc. Brit. 7th ed. iii. 659; Hayden,—Dict. of Dates, 1845, pp. 37, 385.

[3] Ovid,—Fast. iii. 357; Dionys. Hall. ii; Plut.,—Numa. p. 70.

formed the institution of the Salii,[1] whose duties were to guard this symbol from the warlike god of the perpetuity of the Empire,—to which end, eleven similar shields were fabricated,

"Error ut ante oculos insidiantis eat."

Livy[2] records that in the time of Tullus Hostilius, about 650 A. C., a shower of stones fell upon the Alban mount; and this historian remarks that similar events were celebrated by a nine days'-festival,[3]—"Mansit solenne, ut quandocunque idem prodigium nuntiaretur, feriæ per novem dies agerentur." Some time after the battle of Cannæ, in Apulia,—fought in the year 216 A. C.,—a shower of stones fell on the same mount.[4] Calmet mentions a stone which fell in Crete, in 520, during the life of Pythagoras. An extraordinary aërolite is recorded by Pliny,[5] to have fallen during the 78th Olympiad, or about 467 years A. C., near to Egospotamas, in Thrace, and was preserved in his day: it is noticed in the Parian Chronicle. This remarkable mass is said to have been "*magnitudine vehis*"—of great size, and had a burnt colour—"*colore adusto.*" Plutarch mentions that it was much venerated by the inhabitants of the Chersonesus—"For," says he,[6] "about this time there fell out of the aire a marvellous great stone, in the place they call the Goates river, which stone is seene yet unto this day, holden in great reverence by the inhabitants of the city of Chersonesus. It is said also, that Anaxagoras did prognosticate, that one of the bodies tied unto the vault of the heaven, should be plucked away, and should fall to the ground by a sliding and shaking that should happen. Notwithstanding Anaxagoras' words are confirmed by Damachus, who writeth in his booke of religion, that the space of three score and fifteen years [days] together, before that this stone

[1] On the 1st March, in commemoration of its descent, the Salii went through the city, bearing the shields and singing Numa's ditties. Fast. iii. 387; Virg.—Æn. viii. 663; Lucan,—Pharsal. lib. i. 603: Livy, i. 20; Horace,—Ep. II. i. 86; Tacit.—An. ii. 83.

[2] Hist. lib. l. decad. i. 12.

[3] Ib. 25, 30, 34, 35; et alibi passim.

[4] Burder,—Orient. Customs.

[5] Nat. Hist. ii. 58; Diog. Laert. ii. 10; Parian Chronicle.

[6] Plut. Lysander, Fol. 1579, p. 452.

did fall, they saw a great lump of fire continually in the aire, like a cloud inflamed, the which tarried not in any one place, but went and came with divers broken removings, by the driving whereof there came out lightnings of fire that fell in many places, and gave light in falling, as the starres do that fall. In the end when this great body of fire fell in that part of the earth, the inhabitants of the country, after that they were a little boldened from their feare and wonder, came to the place to see what it was; and they found no manner of shew or appearance of fire; but only a very great stone lying upon the ground, but nothing in comparison of the least part of that which the compasse of this body of fire did shew, if we may so name it. Sure herein, Damachus' words had need of favourable hearers!"

Diogenes Laertius states that this stone was supposed to have fallen from the sun, and Aristotle[1] thought it had been carried by a violent wind from another part of our earth. It is to be hoped that this body may yet be discovered. In the year 465, a stone fell near Thebes from a fire-ball;[2] in 461, one fell in the marsh of Ancona;[3] in 343, a shower of stones fell near Rome.[4] Plutarch[5] mentions a shower of *fiery* stones in the year 206 or 205,—when the Romans sent to Pessinus for Cybele "the mother of the gods." Livy[6] records one which fell into the lake of Mars in 176; Pliny,[7] a shower in 90 or 89; and Cæsar,[8] one which fell in 46 at Acilla, in Africa. Coming down the stream of time, we arrive at the Christian era, but before recording any occurrences since the birth of our Saviour, we will briefly notice several falls of meteorlites in China, given on the authority of De Guignes.

In the year 644 A. C., five fell in Song. In 211, one fell from a bolis, creating an extraordinary excitement among the people: "The inhabitants of the district, willing to convey a moral lesson to their unpopular emperor, caused these words to be engraved on the stone,—*Chi-Hoang-Ty draws near to*

[1] Arist.—Met. lib. i.
[2] Aristodemus, quot. by Greek Scholiast of Pindar.
[3] Valer. Max.; Livy,—Lib. vii. cap. 28.
[4] Jul. Obsequens,—De Prodigiis.
[5] Plut. Fab. Max. Fol. 1579, p. 180.
[6] Lib. 41. 3.
[7] Hist. Nat. lib. ii. cap. 56.
[8] Comment.

death, and his empire will be divided. In the plenitude of his indignation, the emperor ordered all the inhabitants of the district to be put to death, and the stone to be broken in pieces; but he died in the course of the following year; and three years after, in the reign of his successor Eul-chi-Hoang-Ty, in consequence of a general revolt, the empire was partitioned into many kingdoms, and the dynasty of the Tsins was extinguished."[1] In the year 192, one fell; in 89, two fell in Yong, with a noise heard over 40 leagues; in 38, six fell in Leang; in 29, four fell at Po, and two at Schingting-fou; in 22, eight fell; in 19, three fell; in 12, one fell at Ton-Korean; in 9, two fell; in 6, sixteen fell in Ning-Tcheou, and two at You. After the birth of Christ, some stones fell in China, in the years 2, 106, 154, 310 and 333.[2]

330. Early in the Christian era we meet with two records of the fall of meteoric stones, the exact dates of which are doubtful,—the one mentioned by Pliny, in the country of the Vocontii; and the other by Mondognetius,[3] in the reign of the Emperor Valentinian, when a shower of stones fell at Constantinople, slaying many cattle and killing several persons. Orosius mentions the fall of one, in 416, at the latter place, but the chronology and facts of this historian are sometimes doubtful. Marcellinus[4] mentions the fall of three in Thrace in 452. In the sixth century, one fell on Mount Lebanon from a fire-ball,[5] and another near Emesa in Palestine. In 616, stones fell in China.[6] In 648, a *fiery* stone was observed at Constantinople. In the ninth century, we find falls recorded in China, in the years 811 and 817,—both from fire-balls, attended with a loud explosion, the former about the fourth hour after noon, the latter about the same time after midnight; and in Japan, in the years 839, 885, 886, and 887.[7] Mezeray mentions a shower of stones in 823, in Saxony; De Sacy, and Quatremére, one in 852, in Tabaristan, and five in December 856, in Egypt. In 897, one fell at Ahmedabad.[8]

[1] Edin. Encyc. vol. xiv. p. 114. [2] Rémusat,—Jour. de Phys. May 1819.
[3] Life of Marcus Aurelius. [4] Chronicon, p. 29.
[5] Photius,—Danascius in Life of Isodorus. [6] Rémusat.
[7] Ma-touan-lin. [8] Quatremere.

In 905, several fell in Corée, with a loud noise. Early in the tenth century, a meteoric stone of great magnitude, fell into the Narni, and projected some height above the water.[1] In 951, one fell near Augsburg ;[2] about ten years after, one fell during a tempest ;[3] and in 998, two fell with a loud sound,—the one in Magdeburg, and the other near the Elbe.[4] In 1021, meteoric stones fell in Africa ;[5] in 1110, one fell into the Lake Van in Armenia ;[6] in 1112, near Aquileja ;[7] in 1135, one fell in Thuringia ;[8] in 1198, one fell near to Paris ;[9] on July 26. 1249, several fell in Saxony.[10] Schottus[11] mentions one which fell in the thirteenth century, at Wurtzburg ; in 1280, one fell at Alexandria.[5] In 1300, or thereabouts, large stones fell in Arragon.[12] On the 1st October 1304, several fell near Friedland or Friedberg, near the Saale ;[13] in 1305, in the country of the Vandals ;[14] on January 9. 1328, several fell in Mortahiah and Dakhaliah.[15] In 1360, several fell in Yorkshire ; on May 26. 1379, stones fell in Hanover.[16]

The fifteenth century is characterised by some very remarkable occurrences of this phenomenon. In 1421, one fell in Java.[17] In 1438, meteorolites fell at Roa, near Burgos, in Spain, during a hunting excursion in which King Don Juan was engaged. Proust, who relates the facts upon the testimony of Cibdaréal, says the shower continued for an hour, after which the falconers remounted and repaired to the spot about half a league distant : the report to the king represented the field as so thickly strewed with spongy masses, that the soil was concealed. The specific gravity of these stones was extremely light. In 1474, two large stones fell near Viterbo.[18] In 1480, stones fell in Germany ; and in 1491, one descended near Crema.[19] In the chronological series we now meet with the famous Ensisheim meteorolite, which fell there on the

[1] MS. Chron. of Benedictus de St Andrea. [2] Albertus Stadius, and others.
[3] Platina,—Life of Pope John XIII.
[4] Cosmas and Spangenberg ; Chladni,—Phil. Mag. vol. lxvii. p. 5.
[5] De Sacy. [6] Eretz. [7] Valvasor. [8] Spangenburg. Chron.
[9] Sauval. [10] Spangenberg and Rivander. [11] Phys. Curios.
[12] MS. Chron.—continuation of that of Martinus Polonus.
[13] Albert Krantz, Spangenberg. [14] Bonav. de St Amable.
[15] Quatremere. [16] Lerbecius. [17] Raffles,—Hist. of Java, ii. 137.
[18] Bib. Italiana, Sept. 1820, vol. xix. p. 461. [19] Simonetta.

7th of November 1492, about noon. Maximilian the king was there at the time, and possessed himself of a portion of the mass. Its fall has been thus recorded by Trithemius,[1]—" In the same year, 1492, on the 7th day of November, in the village of Suntgaw, near the townlet of Ensisheim, not far from Basil, a city of Germany, a stone called a thunder-stone, of a prodigious size, for we know from eye-witnesses that it weighed 255 pounds, fell from the heavens. Its fall was so violent that it broke into two pieces. The most considerable is still exhibited at the door of the church of Ensisheim, suspended by an iron chain, as a proof of the fact which we have mentioned, and to preserve it in the public recollection." Paul Lang, a Benedictine monk, observes that it thundered at the time. Another chronicler mentions, that this meteorolite sank into the earth of a wheat-field where it fell, and that the noise attending its descent was heard at Lucerne. This aërolite remained in the church of Ensisheim till the Revolution, when it was removed to Colmar, but it has been restored to its former place. It was analyzed by Vauquelin, and found in all respects to be similar to other meteorolites, containing silica, magnesia, iron, nickel, sulphur, and a small quantity of lime: this result disproves the idea of Barthold,[2] that it is merely a fragment of rock detached from a neighbouring mountain, and conveyed there by aquatic power.

On the 28th of January 1496, three fell between Cesena and Bertonosi;[3] in the same year, a shower of stones fell at Munkbergen. Perhaps about this time, " nostris temporibus," a large meteorolite fell in Lombardy.[4] Cardan[5] describes a fall of stones there in 1510, which has also been noticed by Surius[6] of Cologne, Leonardus, and Bondini. It occurred near the Adda, not far from Milan, at 5 P.M., when about 1200 fell upon the ground, two of which weighed 120 and 60 pounds respectively; the phenomenon was attended by a luminous meteor. The succeeding year, a friar was

[1] Hirsaugiensian Annals; Gesner,—Liber de Rer. Fossil. Figur. cap. iii. p. 66, Opera. Zurich, 1565. [2] Jour. de Physique. [3] Buriel, Sabellicus.

[4] Leonardi,—Speculum Lapidum, 1502, lib. i. cap. 5; Paoli,—Brugnatelli's Jour. 1818; Ann. of Philos. xiii. 228. [5] De rer. variet. lib. xiv. cap. 72.

[6] Comment.; Leonardus,—Mirror of Stones; Bondini,—Theat. Naturæ.

killed at Crema by a meteorolite.[1] In 1516, six stones fell in China, from a clear sky, with a great noise; three of them weighed respectively 27, 15, and 8 pounds.[2] In May 1520, several fell in Arragon.[3] In 1538, a shower of dust and stones fell near Tripergola in Italy, following an earthquake; after it passed away, an island was seen to have arisen in the Lucrine lake,[4]—these were evidently of telluric origin, and not of the same character with the others mentioned. One fell on the 28th April 1540, in the Limousin;[5] on November 6. 1548, one fell at Mansfeldt in Thuringia, with a loud noise;[6] on the 19th May 1552, a shower fell near Schlossingen, also in Thuringia,[7]—Spangenberg carried several of them to Eisleben. In 1559, two, as large as a man's head, fell at Miscoltz in Hungary;[8] on the 17th May 1561, the *Arx Julia* fell in Torgau, at Eilenborg;[9] on the 27th May 1580, stones fell near Göttingen.[10] On the 26th July 1581, between 1 and 2 P.M., one fell from a fire-ball with a loud explosion in Thuringia; it weighed 39 pounds, and sunk in the soil to the depth of 4 feet, tossing up the earth to the height of about 12 feet; it was so hot that nobody could touch it, but after its removal from the spot it was taken to Dresden.[11] On January 9. 1583, several fell in Calabria at Castrovillari.[12] During the Ides of the same month, the inhabitants of Rosa in Lavadie, observed one fall from a black cloud, in serene weather, accompanied by a loud noise; it weighed 30 pounds.[13] On the 2d March, same year, one fell in Piedmont;[13] and two years later, one fell in Italy.[14] On June 19. 1591, several fell at Kunersdorf;[15] on March 1. 1596, several fell at Crevalcora.[16] Cæsius and the Jesuits of Coimbra mention one which fell in the kingdom of Valencia, about this time, the exact date of which is unknown, but it was not in 1603, as has been alleged. In August 1618, a shower of stones and red rain took place in Styria.[17] On the

[1] Giovanni del Prato, and others. [2] Ma-tuan-lin.
[3] Diego de Sayas. [4] Montfauçon,—Diar. Ital. cap. 21.
[5] Bonav. de St Amable. [6] Ib. and Spangenberg. [7] Spangenberg.
[8] Isthuanfi,—Hist. of Hungary; Breslaw Collection, vol. xvi.
[9] Gesner; De Boot. [10] Bange.
[11] Binhard,—Chr. of Thuring.; Olearius. [12] Casto, Mercati, and Imperati.
[13] Mercati. [14] Imperati. [15] Lucas; Angelus,—Annales Marchiæ.
[16] Mitturelli. [17] M. de Hammer,—Fundgruben der Orients.

10th of January 1622, one fell in Devonshire ;[1] and on the 9th of April 1628, several fell near Hatford in Berkshire, one of which weighed 24 pounds.[2] On the 27th October 1634, stones fell in Charollais.[3] Upon the testimony of Francesco Carli of Verona, we learn that, on the 21st June 1635, a bolis of extraordinary brightness shot across the Lago di Garda, followed by an explosion, and something fell in the grounds of the Benedictine monks of Vago; next morning, a stone having the ordinary characters of a meteorolite was discovered; it had penetrated about a yard into the soil. On the 7th July 1635, one weighing 11 ounces, fell at Calce, during a storm ;[4] on the 6th March 1636, while the sky was serene, one fell with a crash, in Silesia.[5] On the 29th November 1637, according to Gassendi,[6] one fell on Mount Vaision, one of the maritime Alps, between the towns of Perne and Guilliaume in Provence. It was accompanied by a terrific explosion, and the fire-ball had an apparent diameter of four feet. The place where it fell was hollowed out to the depth of three feet, and width of nearly one; the snow which covered the ground at the time was melted for five feet around the hole, and the earth had a calcined appearance. The meteoric stone was circular, and in size was compared to the head of a calf; it weighed 38 Parisian pounds, and had a specific gravity of 3.5. On August 4. 1642, one weighing four pounds fell in Suffolk.[7] On the 18th February 1647, one fell near Zwickau.[8] In August 1647, several fell in Westphalia.[9] Between that year and 1654, one weighing eight pounds fell into the sea, killing two men; this is mentioned on the testimony of Olaüs Ericson Willman, a Swedish sailor, in the service of the Dutch East India Company. On August 6. 1650, one fell at Dordrecht ;[10] on March 30. 1654, several fell in Funen.[11] About this time one fell in Milan, killing a Franciscan monk ;[12] and one fell at Warsaw. In June 1668, many fell at Verona, from a fire-ball in a serene

[1] Rumph.
[2] Gent. Mag. Dec. 1796.
[3] Morinus.
[4] Valisnieri,—Opere, vol. vi. p. 64.
[5] Lucas, Seschiche's Chron.; Cluverius,—Geogr.
[6] Opera, Lyons, 1658, p. 96.
[7] Gent. Mag.
[8] Schmid.
[9] Gilbert's Annalen.
[10] Senguerd.
[11] Bartholinus.
[12] Museum Septalianum.

sky ;[1] one of them weighed 300, and another 200 pounds : in an analysis made by Laugier, that chemist detected the presence of *chrome*, which is now considered one of the characteristics of meteorolites. On February 27. 1671, several fell in Suabia ;[2] in 1673, one fell near Dietling ;[3] on the 6th October 1674, two fell in Glaris ;[4] about this time, one fell into a fishing boat at Copenshey, in the Orkneys.[5] In 1677, several fell near Ermendorf, in Saxony ;[6] on May 18. 1680, at London.[7] On the 31st of January 1686, a curious meteoric substance fell at Rauden, in Courland.[8] Although its appearance was not like meteorolites, seeing it resembled a mass of black leaves, yet its chemical composition, together with the circumstance of its descent, render it worthy of a place in the records of these bodies. Baron Grotthus found it composed of silica, magnesia, iron, nickel, chrome, lime, carbon, and sulphur. It fell at the same time in Pomerania and Norway. In January 1697, several stones fell near Siena ;[9] and on May 19. 1698, in Berne.[10]

331. In the first year of the last century, a meteoric stone fell at St Jago in Jamaica. On June 7. 1706, one weighing 72 pounds fell in Macedonia, from a small cloud, attended by a loud explosion.[11] On the 11th April 1715, some fell in Pomerania.[12] In June 1722, several fell in Freisingen ;[13] on June 23. 1723, several fell at Plestowitz in Bohemia, from a small cloud, with a loud noise ;[14] and on July 22. 1727, several fell at Liboschitz, Bohemia.[14] On August 18. 1738, some fell near Carpentras ;[15] on October 25. 1740, some fell at Rasgrad ;[16] about the same time one fell in Greenland.[17] In 1743, one fell in Bohemia ;[14] and on October 12. 1750, at Niort, near Coutances in Normandy.[18] Cavallo mentions one which fell

[1] Valisneri, Montanari, Pr. Carli. [2] Gilbert's Annalen, tom. xxxiii.
[3] Leonardus,—De Gemmis, lib. i. cap. 5 ; Mem. de la Soc. Colomb. Fiorentina, 1747, vol. i. diss. vi. p. 14. [4] Scheuchzer.
[5] Wallace ; Gent. Mag. July 1806. [6] Miscell. Nat. Cur. 1677. [7] King.
[8] Ann. of Philos. No. 91, vol. xvi. p. 68 ; Miscell. Ac. Nat. Curios. ann. 7, pro ann. 1688, in Append. [9] Soldani,—Tr. Acad. Siena, vol. ix.
[10] Scheuzer,—Nat. Hist. Switz. [11] Lucas.
[12] Gilbert's Annalen. vol. lxxi. p. 215. [13] Meichelbeck.
[14] Stepling,—De Pluvia Lapidea. [15] Castillon.
[16] Gilbert's Annalen. tom. 50. [17] Egede. [18] Lalande, Huard.

in January 1753, at Eichstadt, in Germany. On the 3d of July, same year, four meteorolites fell at Strkow, near Tabor:[1] Howard analyzed a fragment, and found silica, iron, nickel, and magnesia; its specific gravity was 4.28. M. de Lalande[2] mentions the fall of two others, in September same year, at Liponas and Pin, near Pont-de-Vesle; one weighed about 20 pounds. In July 1755, one fell in Calabria;[3] in July 1766, one fell at Alboreto, near Milan,[4] with a whizzing noise and long explosion. In August, same year, another fell during a thunder-storm, near Novellara. In 1768, the French Academy of Sciences was presented with meteoric stones which had descended in two different places during that year,—Perigué, about three leagues from Lucé in Maine, and Aire in Artois. The first of these fell from a cloud, with a peal of thunder, about 5 P.M.; it was so hot that it could not be touched, and weighed 7.5 pounds, with a specific gravity of 3.58. One fell at Mauerkirchen, in Bavaria, on the 20th November 1768, at 4 P.M., attended by a hissing sound, and darkness in the atmosphere; it weighed 38 pounds.[5] On the 17th November 1773, one weighing 9 pounds 1 ounce, fell at Sena in Arragon;[6] the sky was perfectly serene at the time when the noise was heard and the meteorolite observed to fall. On the 19th September 1775, one fell near Rodach, in Coburg;[7] about the same time, stones fell at Obruteza, in Volhynia; and in 1776, many fell near Fabbriano, in Santanatoglia, Camerino.[8] In 1779, two fell at Pettiswood, in Westmeath;[9] and on April 1. 1780, several fell at Beeston, in England.[10] In 1782, one fell near Turin;[11] and in 1783, one in France. On the 19th February 1785, several fell in Eichstaedt;[12] and on the 1st October 1787, several fell in Charkow in Russia, accompanied by a rumbling noise.[13]

Upon the 24th of July 1790,—not in August 1789,—a

[1] Stepling,—De Pluvia Lapidea. [2] Hist. Almanac, Presse, 1756; Richard.
[3] Domin. Tata.
[4] Domenico Troili,—Della Caduta di un Sasso dall' Aria Ragionamento. Modena, 1766; Vassallei. [5] Gilbert's Annalen. [6] Proust.
[7] Gilbert's Ann. tom. xxiii. [8] Soldani, Amoretti.
[9] Gent. Mag. Sept. 1796. [10] Lloyd's Even. Post. [11] Tata, Amoretti.
[12] Pickel, Stutz, Baron Moll. [13] Gilbert's Annalen, tom. xxxi.

shower of stones, which appeared soft on their descent, fell near Barbotan, in the *landes* of Bourdeaux. It was about 9.5 P.M., says M. Baudin, when walking with M. Carris of Barbotan in the court of the castle of Mormés, when the air was calm and the sky clear, a bolis appeared, whose effulgence obscured the moon's light. It was a fire-ball which tapered to a tail, proceeding from S. to N. with great celerity, and split with a noise like a bomb. The interval which elapsed between the bursting of the fire-ball and the sound, led to the calculation that its altitude was eight miles; after the sound had ceased, a hollow echo from the chain of the Pyrenees was heard, and after continuing about four minutes, died away; a sulphureous odour was observed at the time. This meteor appears to have exploded at a little distance from Juillac, near to Barbotan, and scattered stones of various sizes over a circular space of about two miles diameter: some weighed 18 pounds, and others more; one which was taken to Mont-du-Marsan, weighed 25 pounds. One of the stones, which was 15 inches in diameter, is said to have broken through the roof of a dwelling and killed a man and bullock, but in the *procès verbal*, it is stated that they did no harm to any one, and excepting some trees which were broken, no injury was sustained. The bolis which accompanied these aërolites was seen at Bayonne, Auch, Pau, Tarbes, Bourdeaux, and Toulouse.[1] In May 1791, stones fell in Tuscany.[2] Upon the 16th of June 1794, a remarkable fall of meteorolites took place at Siena, which was described by the late Earl of Bristol, and the Abbate Soldani.[3] It occurred about eighteen hours after the eruption of Vesuvius.[4] At 7 P.M. a cloud of alarming aspect appeared in the north, discharging lightning, and throwing out what seemed to be smoke, with loud explo-

[1] Jour. des Sc. Utiles. Montpellier, 1790; Décade Philos. 1796. [2] Soldani.

[3] Ph. Tr. 1795,—Sir W. Hamilton; Soldani,—Account of the Tuscan Meteor.

[4] The distance of this volcano from the place where they fell is 250 miles. We mention this fact, because, before the physical and chemical characters had identified the Siena meteorolites with others, many were disposed to regard them as of telluric origin, and discharged from Vesuvius. Soldani, Professor of Mathematics in that town, boldly maintained their independence. The opinion generally held at that time, shews how apt we are to err in judgment, from false combinations of coexisting circumstances.

sions. About twenty stones were precipitated to the earth, one of which weighed 5.5 pounds, and had the specific gravity of 3.35. On the 13th April 1795, several fell in Ceylon.[1] One weighing 56 pounds fell on the 13th of December 1795, near Wold Cottage, Yorkshire,[2] and the following year it was exhibited in London. It has been described by Major Topham, who says that it fell within two fields of his house, about 3 P. M., attended by a loud explosion, and penetrated nineteen inches below the surface of the ground, fixing itself firmly in the chalk. On the 4th of January 1796, several fell in Russia;[3] on the 19th February, same year, one weighing 10 pounds fell in Portugal.[4] The Marquis de Drée[5] gives a circumstantial account of one which fell, on the 12th March 1798, near Ville Franche, in the Department of the Rhône. It occurred about 6 P. M., attended by a bolis which was seen at Lyons, and on Mont Cenis, and a hissing sound. One of the fragments of this aërolite fell in the vineyard of Pierre Crépier of Salés, excavating a hole about 20 inches deep and 18 inches wide; it was hot, smelled of gunpowder on its descent, and weighed 20 pounds. On the 19th December, same year, about 8 P. M. several fell from a fire-ball in Bengal; one of them, which was of considerable magnitude, fell at Krakhest, on the north side of the Goomty, about fourteen miles from Benares. The sky was serene at the time when the effulgence of the meteor attracted attention, a loud peal of thunder was heard, and the sound of heavy bodies falling immediately followed; clouds had not been seen since the 11th, nor did any appear for several days after the 19th. Several of the meteorolites buried themselves in the ground; one weighing two pounds broke through the roof of a house and penetrated the hardened clay floor. Mr Howard,[6] who describes these meteoric stones,—specimens of which were sent to Sir Joseph Banks,—says, they were of various sizes, from 3 to 4 inches in diameter, and in appearance exactly similar: he adds,— "It is well known there are no volcanoes on the continent

[1] Le Beck. [2] Gent. Mag. 1796; Ph. Tr. 1802.
[3] Gilbert's Annalen. tom. xxxv. [4] Southey,—Let. from Spain.
[5] M. de Drée,—Jour. de Phys. [6] Ph. Tr. 1802; Lord Valentia.

of India; and, as far as I can learn, no stones have been met with in the earth in that part of the world, which bear the smallest resemblance to those above described." On the 5th of April 1799, several fell at Batonrouge on the Mississippi,[1]—and with them we close the historical record up to the present century.

332. Upon the 5th of April 1800, a luminous meteor of extraordinary magnitude darted across a portion of the American continent, disappearing with a rushing noise and explosion, causing a sensible vibration of the earth. Unsuccessful search was made for this body, although the place of its descent was indicated by scorched vegetation and the earth's surface being disturbed. In the year 1801, stones fell from a bolis, on the Isle aux Tonneliers.[2] In September 1802, stones fell in Scotland;[3] and during the same year, near Allahabad.[4] One of the most remarkable meteoric showers on record, took place about 1 P.M. on April 26. 1803, at L'Aigle, near to Caën, in Normandy. M. Biot,[5] who repaired to the spot to collect authentic information, addressed a letter to the minister of the interior, upon the subject.[6] From the evidence adduced, it appears that a fire-ball moving towards the south had been observed, followed by a violent explosion. The phenomenon seemed to be connected with a small cloud of rectangular form, to the N.N.W. of L'Aigle, at a considerable altitude; a hissing noise was heard over the entire canton, and an amazing number—nearly 3000—of meteoric stones descended. It was observed that the direction of the shower was exactly in the line of the magnetic meridian; these masses were projected over an elliptic surface of 2.5 leagues in length and one in breadth; the largest weighed seventeen pounds. On the 4th of July, same year, a meteorolite struck a house at East Norton;[7] on the 5th October, several fell near Avignon;[8] and on the 13th December, one fell from a dark sky about noon, at St Nicholas, in Bavaria.[9] On the 5th of April

[1] Belfast Chron. of the War.

[2] M. Bory de St Vincent,—Voy. dans les Isles des Mers d'Afriq. iii. 253.

[3] Mon. Mag. Oct. 1802.

[4] Ed. Jour. of Sc. vol. ix. p. 172.

[5] Relation d'un Voy. fait dans le Départ. de l'Orne; Mém. de l'Inst.

[6] Jour. des Débats.

[7] Liter. Jour.; Phil. Mag.; Bibl. Brit.

[8] Bibl. Brit.

[9] Imhof.

1804, one fell at Possil, near Glasgow,[1] which broke into two on its reaching the earth; the sound of the explosion extended to Falkirk; upon the 6th of October, same year, one weighing seven pounds fell near Apt, in the department of Vaucluse, with an explosion heard for fifteen leagues round, but unaccompanied by a fire-ball.[2] About this time, or a little later, one fell near Dordrecht.[3] On March 25. 1805, several fell in Siberia;[4] in June, same year, several fell in Constantinople.[5] On the 15th March 1806, two fell near Alais, one at St Etienne de L'Olm, and the other at Valence;[6] on the 17th May, same year, one fell in Hampshire;[7] on March 13. 1807, one fell in the government of Smolensko,[8] weighing 160 pounds. On the 14th December, same year, about 6.5 A.M., several fragments fell from a bolis which issued from a black cloud, at Weston, Connecticut; some of them weighed from 20 to 35 pounds.[9] On April 19. 1808, at 1 P.M., several fell at Borgo San-Domino, near Parma and Placenza;[10] on the 22d May, same year, at 6 A.M., several fell at Stannern, in Moravia, scooping out a tract two feet long and two inches deep,[11]—their specific gravity was 3.19. On the 3d September, same year, at 3.5 P.M., several fell near Lissa, in Bohemia,[12] having the specific gravity 3.56; and that year several fell near Moradabad.[13] On the 17th June 1809, one weighing 6 ounces fell at sea, in N. lat. 30° 65′ and W. long. 70° 25′ on board an American ship.[14] On the 30th January 1810, at 2 P.M., several fell in Caswell County, North America; the sound was heard at the distance of thirty miles from the spot.[15] In July, same year, a large stone fell at Shadabad, in the East Indies,[16] from a fire-ball,—it "burned five villages, destroyed the crops, and some men and women." In August 1810, one fell from a black cloud, with a hissing noise, in Tipperary; it weighed 7.75 pounds, and had a specific gravity of 3.67; when

[1] Phil. Mag.; Bibl. Brit.
[2] Annales de Chimie, No. 144.
[3] Van Beck-Calkoen.
[4] Gilbert's Annalen, tom. xxix. xxxi.
[5] Kougas-Ingigian.
[6] Jour. de Phys. 1806.
[7] Mont. Mag.
[8] Gilbert's Annalen.
[9] Amer. Acad. of Arts and Sc. vol. iii.; Nich. Jour. vol. xxviii.; Med. Rep. 1807.
[10] Guidotti; Spagnoni.
[11] Bibl. Brit.
[12] De Schreibers.
[13] Ed. Jour. of Sc. ix. 172; Ed. Cab. Lib.—Brit. Ind. iii. 253.
[14] Med. Repos.
[15] Phil. Mag. vol. xxxvi.; Med Repos.
[16] Phil. Mag. vol. xxxvii. p. 236.

dug out of the ground it was hot.[1] On the 23d November, same year, three fell in Charsonville, Loiret, near Orleans.[2] The day was calm and the sky serene when the phenomenon occurred, and no luminous body was seen to accompany it; they fell at 1.5 P.M., sinking perpendicularly into the ground, one to the depth of a yard: two only were discovered, that which fell at Villenoi weighed about 20 pounds, the other, at Moulin-Brûlé, weighed 40 pounds; both were long in cooling before they could be removed. A meteoric stone weighing 15 pounds fell on the 12th of March 1811, near Romea, in Russia;[3] and on the 8th of July, same year, several fell at Berlanguillas, in Spain.[4] A number fell about 8 P.M. on the 10th April 1812, near Toulouse,[5] at two leagues W.N.W. of Grenada; a very brilliant light suddenly broke out, and three loud detonations were heard even at Castres, twenty leagues from the spot. On the 15th of April, same year, one fell at Erxleben, in size equal to a child's head;[6] and on the 5th of August, same year, several fell in the department of La Vendée.[7] On the 14th March 1813, some fell at Cutro, in Calabria,[8] during the descent of red dust. In the autumn of the same year, several fell near Malpas, in Cheshire,[9] from a bright cloud, about 1 P.M.; the atmosphere was very warm and calm at the time, and the meteorolites were intensely hot upon their descent.

In September 1813, several fell from a black cloud in a serene sky, at Scagh, in Limerick;[10] one weighed 17 pounds; another, which was broken in two pieces, weighed 65 pounds, and a third 24 pounds. About this time one fell at Pulrose, in the Isle of Man.[11] On the 3d February 1814, several fell in Russia.[12] On the 5th September, same year, at noon, while the sky was serene, a violent explosion was heard in the department of Lot and Garonne, which was followed by a rumbling noise and the fall of aërolites near Agen; they fell

[1] Phil. Mag. vol. xxxviii.
[2] Nicholson's Journ. vol. xxxix. p. 158.
[3] Gilb. Annal. tom. xxxviii.
[4] Bibl. Brit. vol. xlviii. p. 162.
[5] M. D'Aubuisson.
[6] Gilb. Annalen, tom. xl. xli.
[7] Brochant.
[8] Bibl. Brit. Oct. 1813.
[9] Ann. of Philos. Nov. 1813, vol. ii. p. 396.
[10] Phil. Mag.
[11] Murray,—Phil. Mag. July 1819. p. 39.
[12] Gilbert's Annalen, tom. l.

obliquely at an angle of 65°, and two of them weighed 18 pounds each.[1] On the 5th November 1814, nineteen fell at Futtypore in the Doab. Dr Tytler mentions that on the evening of that day, a meteoric stone fell about seventy miles N.W. of Allahabad, at a place called Rourpoor, and that the meteor was seen exactly at the same time at Hazareebug in Bengal, 250 miles east of Allahabad. This fire-ball was of large size, and exploded with a loud detonation; the mass looked on its descent, as if covered with pitch, and had a sulphureous smell.[2] On the 18th February 1815, one fell at Duralla, in India;[3] and on the 3d October, same year, at 8 P.M., a large aërolite fell at Chassigny, near Langres,[4] from a dark cloud with a loud explosion. Dr Pistollet of Langres collected some fragments of this meteorolite which M. Vauquelin analysed; the composition was somewhat different from other meteoric stones, in having an excess of magnesia and chrome, and remarkable in the absence of nickel. In 1816, one fell in Somersetshire;[5] and there is reason to believe that in May 1817, one fell into the Baltic, from the brilliant bolis of Gottenburg. On the 15th February 1818, a large meteorite, which descended from a fire-ball, fell in a garden to the south of Limoges,[6] excavating a hole in the earth of considerable size. On the 30th March, same year, one fell near Zaborzica, in Volhynia,[7] which was analysed by Laugier; and on the 10th of August, same year, one weighing 7 pounds fell from a bolis in Smolensko, penetrating nearly sixteen inches into the ground.[8] On the 13th of June 1819, one fell at Jonzac, which has been analysed by Laugier,[9] who found nickel wanting altogether, alumina and lime in larger proportion than usual, and a deficiency of sulphur and magnesia. On the 5th of September, same year, about noon, there fell from a small insulated cloud, a shower of small pieces of earth.[10] On

[1] Annal. de Chim. tom. xcii.; Phil. Mag. vol. xlv.
[2] Phil. Mag; Brit. Ind. vol. iii. Ed. Cab. Lib.
[3] Phil. Mag. Aug. 1820. p. 156.
[4] Annal. de Chim. et Phys. i. 45.
[5] Phil. Mag.
[6] Gazet. de France; Jour. de Commerce, Feb. 25. 1818.
[7] Ann. de Museum. 17. Ann. ii.
[8] Ed. Jour. of Sc. No. ii.
[9] Annal. de Chimie, et de Phys. xiii. 441.
[10] Hesperus, Nov. 1819; Gilb. Annal. vol. lxviii.

the 13th October, same year, some descended in the Principality of Reuss.[1] In March 1820, during the night, one fell at Vedenburg, in Hungary.[2] Upon the 12th of July, same year, between 5 and 6 P.M., meteorolites fell in Courland, from a fire-ball having an apparent diameter equal to that of the moon, and a reddish colour. The meteor moved slowly from S. to N., and having described an arc of 100°, became extinguished; a noise like three discharges of cannon followed, and there was a continued rolling. At that instant a stone fell in the circle of Dunaborg, penetrating 1.5 feet into a clayey loam, and weighing 40 pounds—it smelled of gunpowder and felt hot. At the same time another fell into the lake of Lolupschin, about four versts distant from the former place; and three versts in an opposite direction, another fell into the river Dubna.[3] Grotthus analysed this meteorolite. On the 13th October, same year, one fell near to Köstritz, in Russia, which was analysed by Stromeyer.[4] One descended from a fire-ball, in a clear sky, and while the sun was shining brightly, about 3 P.M., on the 15th June 1821, at Juvenas in Ardêche;[5] this aërolite, which weighed above 200 pounds, and sunk five feet into the ground, is remarkable for vesicular cavities in its crust, and the absence of nickel. A *proces-verbal* drawn up by the Mayor of the Commune, is a curious specimen of superstition, in illustration of which we will be pardoned making the following extract:—"The alarm was such, that it was not till the 23d of the month that they resolved to dig out this prodigy, of which they knew neither the form, the nature, or the substance. They deliberated for a long time, whether they should go armed to undertake this operation which appeared so dangerous; but Claude Serre, the sexton, justly observed, that if it was the devil, neither powder nor arms would prevail against him, that holy water would be more effectual, and that he would undertake to make the evil spirit fly; after which they set themselves to work, and after having sunk nearly six feet, they found the aërolite!"

[1] Gilbert's Annalen. lxiii. [2] Hesperus. xxvii. cal. 3.

[3] Ed. Phil. Jour. vol. vi. p. 384; Gilb. Annal. tom. lxvii.

[4] Gilbert's Annal. lxiii. 451.

[5] Jour de Phys. tom. xcii. p. 463; Ann. of Philos. vol. xx. p. 72.

On the 3d of June 1822, several fell from a bolis at Angers;[1] it occurred at 8 P.M., and was attended by a very loud detonation, followed by a sound resembling a running fire of musketry. The bolis was seen to the S.E. of Angers, and was visible at Loudun, sixteen leagues off. Professor Boisgiraud describes the meteor as having been seen at Poitiers, in the N.N.E., and says that the nucleus did not change its position respecting the stars α and β *Aurig.*, although the phenomenon continued several minutes. On the 7th of August, same year, one fell at night, near Kadonah, in Agra, accompanied by a loud noise and rushing wind; five years afterwards it was exhibited in London. On the 10th of September same year, one fell near Carlstadt, in Sweden; and three days after, at 7 A.M., during a thunder-storm, one fell near Baffe, Departement des Vosges.[2] On the 13th December 1822, some meteoric stones fell near Loutolox, in Savitaipal, Wiborg, in Finland; no nickel could be detected.[3] On the 7th August 1823, one descended near Nobleborough, in America.[4] The phenomenon occurred about 5 P.M., the sky was clear excepting a small whitish cloud, apparently forty feet square, near the zenith, and the atmosphere was perfectly calm. As if from this cloud, a noise, like the discharges of platoons of soldiers, proceeded, and immediately thereafter it assumed a rapid spiral motion downwards—the stone now fell, and penetrated the ground about six inches; when found, it exhaled a sulphureous odour. On the 15th of January 1824, between 9 and 10 P.M., a fall of stones took place, about twenty-one miles from Cento, in Ferrara. Brilliant flashes and a loud noise attended the phenomenon. The sound is described as having first resembled the discharges of artillery, then the firing of musketry, and in a short time it changed, so as to resemble a number of bells ringing at once; one of these

[1] Ann. de Chimie, xx. 89; Ann. of Philos. xx. 313.

[2] Ann. de Chimie, tom. xxi. p. 17.

[3] Algemeine Nordische Annalen der Chemie, of Scheerer, i. 174; Ed. Phil. Jour. ix. 333. In Chladni's Catal. (Ann. of Philos. vol. xxviii.) this phenomenon is recorded in the year 1814.

[4] Silliman's Amer. Jour. vol. vii.; Phil. Mag. lxiii. 16–19; Ann. Phil. vol. xxiii. p. 236.

aërolites weighing 12 pounds is preserved in Bologna.[1] In the same year, one fell in the province of Irkutsk, in Siberia; and on October 14. same year, one preserved in Prague, descended near Lebrak, in Bohemia. One fell at Nanjemoy,[2] in Maryland, North America, on the 10th of February 1825, a little after noon, with a loud explosion and a whizzing noise. It entered the ground to the depth of about eighteen inches, and weighed 16 pounds 7 ounces; it was sensibly warm, and had a strong sulphureous smell. A fragment, weighing about 4 pounds, was sent to Professor Silliman by Dr S. Carver, and analysed by Mr Chilton.[3] The surface was covered with a black vitreous coating, divided into polygons resembling honeycomb; its specific gravity equalled 3.66. On the 27th September 1825, one fell in the Sandwich Islands.[4] In 1826, stones fell in Georgia, causing the death of several persons.[5] Several meteorolites fell on the 27th February 1827, in the district of Azim Gerh, in India; chrome and nickel were detected, and the specific gravity of the meteorolite examined was 3.5.[6] On the 8th of October same year, several fell from a black cloud at Belostok, about 10 A.M.—a rumbling noise attended, and one of the aërolites picked up weighed 4 pounds.[7] In July 1829, Alika, an Indian, was killed by an aërolite.[5] On the 15th February 1830, at 7.5 P.M., one fell at Launton in Oxfordshire, entering the ground obliquely from the N.E.; it weighed 2 pounds 5 ounces. This meteorolite was accompanied by a bolis and a triple explosion, which was heard at the distance of four miles; the day had been foggy, with a north wind; the temperature at 10 A.M. and 10 P.M. was 43° and 26° F. respectively, and the barometer, at the same hours, so high as 30.9 and 30.8 inches. The stone was friable, interspersed with slender veins of iron, and granular metallic particles, highly magnetic, and had a ferruginous crust. At the close of 1833, some meteoric stones were found at

[1] Diario di Roma; Bullet. des Sciences.

[2] Silliman's Amer. Jour. June 1825; Ann. of Philos. xxvi. 186.

[3] Ann. of Philos. xxvii. p. 149.

[4] Silliman's Amer. Jour. vol. xlix. p. 407; Jameson's Edin. New Philos. Jour. 1846, vol. xl. p. 204.

[5] Athen. 1836, p. 803. [6] Edin. Jour. of Sc. ix. 172. [7] Ib.

Blansko, in Moravia,—a few nights previously, a very luminous meteor appeared, accompanied by a noise like thunder.[1] Several fell during a lunar eclipse, on December 10. 1834, at Marsala and its environs ; they were as large as walnuts, spherical, dense, and yellowish. The preceding day was tranquil, and the night was one of exquisite beauty ; suddenly a dark spot appeared in the north, which increased quickly ; immediately there blew a violent wind, accompanied by thunder and rain—the houses were shaken—the sea roared—and the people were filled with terror ; excessive cold followed.[2] Upon the 11th December 1836, about 9 P.M., several fell in Brazil, in a line extending more than ten leagues ; they were preceded by a fire-ball of great size and brilliancy, which burst with a loud crackling noise over Macao, at the entrance of the Rio Assu. They fell through the roofs of several houses, deep into the ground, killing and maiming a few oxen ; those found in the sand weighed from 1 to 80 pounds.[3] On the 15th April 1837, one which weighed above 6 ounces, was found in Austria. A curious earthy meteorolite fell in 1839, at the Cape of Good Hope : this anomalous body afforded Professor Powell[4] a new instance of a non-metallic substance possessing the property of elliptic polarization of light by reflexion. One fell from a bolis in a bright starlight night in October 1840, in Concord, New Hampshire ;[5] it descended about two hours after sunset. Its surface was glazed with greyish-white enamel, and shewed signs of intense heat ; the composition was peculiar, and resembled that of the Bishopville meteorolite in South Carolina which Professor Shepard designated *chladnite*.[6] On August 10. 1841, about 9.5 P.M. an immense number of minute stones fell at Iwan from west to east, at an angle of 45° ; their colour was blackish-brown externally, and light brown within ; they were spheroidal, with many irregularities.[7]

Thousands of meteoric bodies fell in September 1841, in

[1] Athen. 1834, p. 36. [2] Giornal della Due Sicilie, Jan. 14. 1835.
[3] Pog. Annal. ; Ed. Jour. Nat. Hist. Sept. 1838, p. 160 ; Athen. 1837, p. 915.
[4] Brit. Assoc. 1846. [5] Silliman's Amer. Jour. N.S. No. 12, Nov. 1847, p. 353.
[6] Ib. 2d Ser. vol. i. p. 381. [7] Allegemeine Zeitung ; Times, Oct. 27.

Hungary, most of which were not larger than hailstones. On the 16th of September 1843, some descended from a clear sky, with a loud noise, at Kleinwenden near Mühlhausen. On the 8th of May 1846, meteoric stones fell at Ancona. One fell on December 25. same year, near Mindethal, Bavaria;[1] at 2 P.M. a noise like distant thunder was heard over a circle of eighteen leagues,—after many nearly uniform discharges, the noise changed to a rumbling sound which lasted about three minutes, and was heard overhead by all observers in that extensive district. A black ball was seen descending at the village of Schonenburg, to the west of Mindthal, and a sulphureous odour was perceived,—the meteoric stone fell in a garden there, and buried itself two feet below the surface; it was an irregular truncated pyramid, with four narrow lateral surfaces, and a fifth somewhat wider, the base was smooth. It weighed nearly 8 kilogrammes,[2] and looked like greenstone with crystals upon its surface, especially some octohedral crystals of iron. One fell at 3 P.M. on the 25th February 1847, nine miles south of Marion, Linn Co. Iowa, attended by an explosion which was heard forty miles off; it weighed 42 pounds; snow covered the ground at the time.[3] On the 19th March 1847, about 2 A.M., a bolis appeared in the east off the coast of Aberdeenshire, which grew in brightness till its effulgence equalled the full moon,—it burst with a perceptible noise, near the ocean: this was doubtless the fall of a meteorite. In July same year, one resembling cast-iron fell at Braunau, with a loud noise; a splendid bolis was seen the same day at Carlsbad.

333. It is mentioned by Mrs Somerville,[4] that "the volume of several meteoric stones has exceeded that of the planet Ceres, which is about seventy miles in diameter. One which passed within twenty-five miles of us, was estimated to weigh about 600,000 tons, and to move with a velocity of about twenty miles in a second,—a fragment of it alone reached the earth." Altogether, upwards of two hundred falls have been recorded

[1] Augsburg Gazette. [2] A kilogr. = 15433 Eng. grains.
[3] Silliman's Jour. N. S. No. 11, p. 288.
[4] Connex. Phys. Sc. xxxvi. We presume the diameter of the *bolis* is meant.

by Chladni,[1] Van Hoff,[2] and others, but many meteorolites must escape our observation, finding a resting-place on uninhabited wastes, and mingling with "the treasures of the deep."

334. Besides these, masses of *Native Iron*[3] have been observed to fall from the atmosphere, and others have been found in situations which render it in the highest degree probable that they have had a similar origin. The date of the "thunderbolt" which fell before the Christian era, from which the sword of Antar[4] was forged, is uncertain. The Parian Marbles[5] mention the descent of a mass of iron on Mount Ida, in Crete, in the year 1168 A.C.; and Pliny records the descent of spongy iron in Lucania, about the year 52. Avicenna affirms that he saw a mass of iron fall in the year 1009 of the Christian era, in Djordjam; and Fabricius mentions the fall of iron in 1164, during the feast of Pentecost. In 1368, a mass of iron fell in the Duchy of Oldenburg; about 1545, a mass fell in the forest of Naunhoff, between Leipsic and Grimma, in Saxony;[6] and in 1618, a metallic mass fell in Bohemia.

A remarkable mass, described by Colonel Kirkpatrick, and recorded in the memoirs of the Emperor Jehangire, is said to have fallen on the 17th April 1620, in the purgunnah of Jalindher. Its descent was accompanied by a luminous appearance and terrific noise; the ground for many feet where it fell was burned up, and the iron was found to be hot when dug out,—it weighed 160 tolahs, or 60 troy ounces. This mass was not malleable till mixed with common iron, but two sabres, a knife, and dagger were made from it. On the evening of the 26th May 1751, when the sky was clear, a bolis shot across the sky from W. to E. with a hollow sound, near

[1] See Chladni,—Ueber Feuer-Meteore, und über die mit denselben herabgefallenen massen. Vien. 1819; Gilbert's Annalen der Physik; Jour. de Phys. Oct. 1818; Annals of Philos. vol. xxviii.

[2] Poggend. Annalen.

[3] Fer natif meteorique,—*Haüy;* Gediegen Eisen,—*Werner;* Octaedrisches Eisen,—*Mohs;* Terrestrial native iron,—*Jameson.*

[4] Antar,—Hamilton, p. 152; Quart. Rev. xxi. 225.

[5] I. 22.

[6] Albinus,—Chron. of Mines of Misnia.

Hradschina, in Agram, Croatia ; it exploded loudly, emitted smoke, and dropped two masses of iron in the shape of chains welded together. A short time ago, meteoric iron was found in Germany, lying about four feet below the surface of the ground. Stromeyer[1] who analysed it found, besides nickel and cobalt, a considerable quantity of the very rare metal molybdenum, and in addition, arsenic, capillary copper and variegated copper-ore, besides a trace of sulphuret of silver. The composition of this mass is thus anomalous, and differs but slightly from another mass from the Hartz Mountains examined by the same chemist.

One of the most celebrated masses of native iron was found by Pallas[2] on the summit of a mountain between Abakansk and Belskoiostrog, on the river Jenisey, in Siberia. It was seen first by Medvedief, who in 1750 discovered a rich vein of iron-ore traversing compact hornstone about 150 yards to the east ; it was reposing on the ridge of the elevation without adhering to the rock, in the midst of fir-trees. It is of a spongy texture and cellular, the cavities being filled with a different mineral, flexible and malleable, but upon being fused, brittle ; it weighed 1680 pounds Russian.[3] The Tartars report that it fell from heaven, and they hold it in great veneration.[4] In 1749 this mass was removed to the adjoining town Krasnojorsk, and in 1772 to the Imperial Academy of Sciences at St Petersburg. Don Rubin de Celis[5] describes a mass found at Otumpa, in the Viceroyalty of Peru, about 500 miles N.W. of Buenos Ayres, which weighed 15 tons. "It was nearly imbedded in white clay, and the country round it was quite flat and without water." Doubts have been hazarded that this mass is not of meteoric origin, nevertheless 10% of nickel enters into its composition, but merely the outcropping of a rich vein of iron-ore.[6] This mass is probably identical with a large specimen in the British Museum. In the year

[1] Phil. Mag. No. 118 ; Roy. Soc. Göttingen.

[2] Phil. Tr. 1776, p. 523 ; Voy. de Pallas, tom. iv. p. 545. Paris 1793.

[3] A pound Russ. = 0.90264 lbs. avoird.

[4] Chladni on the Siber. Mass of Iron, 1794.

[5] Phil. Tr. 1788. vol. lxxviii. p. 37,—*Spanish.*

[6] Phillips,—Mineralogy, 3d ed. 1823, p. 215 ; Phil. Trans. 1786.

1762, while Maximilian Prince of Saxony was at the Baths of Aachen, Löber, his physician, observed in the pavement a very large mass of native iron,—it was dug up, but subsequently lost. In 1812, Dr Chladni endeavoured to rediscover this interesting mass, and through Couver, the old town secretary, who knew of its removal in 1762, learned that it was reposing in its original locality, but plastered over. Couver gave this information and in a fortnight died. Through Professor Weiss, an order was obtained from Prince Hardenberg, to search for the mass, and it was at length found. It was irregular in shape and nearly oval; it weighed about 10,000 pounds, had a specific gravity of 6.7, and was found to contain arsenic.[1]

Native or meteoric iron has been met with also in Baffin's Bay, by Ross;[2] in Mexico, near Durango,[3] mentioned by Humboldt, weighing 40,000 pounds; in Louisiana,[4] where there is a mass weighing 3000 pounds; in Brazil, *en route* from Bahia to Oeyras, where there is a mass measuring about 30 cubic feet, and weighing about 17,300 pounds *French*—Spix and Von Martius;[5] on the oriental Cordillera, in Columbia, near Santa Rosa, weighing 15 cwts.;[6] in the town of Zacatecas, where there is a mass discovered by Sonneschmidst in 1702, weighing about 200 pounds troy; in Iceland, according to a book written in the 13th century, under the reign of Snorro;[7] at the Cape of Good Hope,[8]—Van Marum, and De Dankelmann, but supposed by Barrow[9] not to be genuine; in the Sahara, Africa,—Golberry and Colonel O'Hara; in France,[10] weighing about 1100 pounds; in Belgium weighing 68 pounds, and encrusted on its discovery with garden soil,—

[1] Gilbert's Annalen, Dec. 1814, tom. xlviii. p. 410.

[2] Account of Exped. to Arctic Reg.; Ed. Jour. of Sc. i.

[3] Azara's Trav.—Walkennaer; Villagra,—Hist. de la Nueva Mexico.

[4] Ed. Jour. of Sc. vol. ii. 138; Sil. Jour. vol. iii. 15.

[5] Trav. in Brazil; Mornay, and Wollaston,—Phil. Tr. 1816, p. 270, 281.

[6] Mariano de Rivero, and Boussingault,—Ed. Phil. Jour. vol. xi. p. 120; Annal. de Chimie, tom. xxv.

[7] Speculum Regale; Annal. of Philos. vol. xx. p. 470.

[8] Haarlem Trans. Brande's Jour. vol. vi. p. 162.

[9] Trav. in Africa.

[10] Edin. Jour. of Sc. vol. x. 368.

Stas.[1] There are specimens in Gotha, and in the Imperial Cabinet of Vienna, the latter being supposed to have come from Norway; in New York, from New Orleans near the Red River;[2] and there is a large mass nearly 40 feet high, in eastern Asia, near the source of the Yellow River, said by the Moguls to have fallen as a fiery meteor,—Abel Rémusat.

Referring to the curious discovery by Sir James Alexander, of masses of meteoric iron on the eastern bank of the Great Fish River, in Africa, which contain 4.61% of nickel, Sir John Herschel[3] observes,—"If a meteoric origin be attributed to all these, a shower of iron must have fallen, and as we can imagine no cause for the explosion of a mass of iron, and can hardly conceive a force capable of rending into fragments a cold block of this very tenacious material, we must of necessity conclude it to have arrived in a state of fusion, and have been scattered around by the assistance of the air or otherwise in a melted, or at least softened state."

335. Aërolites descend in conic sections, forming variable angles with the horizon. The celerity of their fall is not uniform, nor does it seem to be in the direct ratio of their weight. Their specific gravity averages 3. The force of cohesion is variable; thus some have been flattened on their reaching the earth, *e.g.* those of 1753, 1768, and 1808. A remarkable encrustation characterises them: it is not deep, but presents physical characters different from the mass. This crust is often of a pitchy lustre, and of great hardness, and with rare exceptions may be accounted always present. It appears due to sudden and great heat, acquired probably at the time when the bolis which generally attends it, flashes in the heavens and expires.

From the records of 126 of these meteoric bodies, we find that ten occurred in the month of January, eight in that of February, thirteen in March, twelve in April, twelve in May, twelve in June, fourteen in July, ten in August, nine in September, eleven in October, eight in November, and seven in December. From these data it appears that twenty-five fell

[1] Athen. No. 425, 1835. [2] Amer. Min. Journal, vol. i.

[3] Notice read before Lit. and Sc. Inst. S. Africa.

in winter—December, January, and February; thirty-seven in spring—March, April, and May; thirty-six in summer—June, July, and August; and twenty-eight in autumn—September, October, and November: or in the following ratios:—19.84%, 29.36%, 28.59%, 22.21% respectively. Of thirty-two, twenty-two fell after noon, and ten before noon; nine between 11 A.M. and 2 P.M.; fifteen between 2 and 9 P.M.; and eight between 9 P.M. and 11 A.M.

From forty-three recorded falls, Shearman[1] found that twenty-nine took place during hot and serene weather; twelve were accompanied by hail, of which those of 1249 and 1552 may be mentioned; and the remaining two fell while thin clouds were floating in the air: of the twenty-nine mentioned, twenty seemed to proceed from a cloud of defined and circular shape, of which the colour was often black. The fall of stones and the occurrence of earthquakes have not unfrequently been observed to coincide, *e.g.* in the years 1618, 1650, 1654, 1668, 1674, 1723, 1743, 1753, 1755, 1768, and 1812.

336. In physical characters and chemical compositions, all meteorolites are nearly alike. The following ultimate ingredients have been detected:—Aluminum, sodium, potassium, magnesium, calcium, and silicon,—all in combination with oxygen; hydrogen, in union with one or more of these elements; iron, nickel, copper, manganese, tin, arsenic, cobalt, and chrome; carbon, phosphorus, and sulphur. These, according to Berzelius, give rise to the following products:—*metallic iron*, in union with variable proportions of the other metals, and carbon; *magnetic iron; sulphuret of iron; meteoric olivine*, similar to the same terrestrial mineral; *chromate of iron; oxide of tin*; *silicates* insoluble in acids. Dr John of Berlin observes regarding the union of the iron with sulphur, that the latter substance is not combined with the whole of the iron, but only with a small portion of it, probably with that portion which is met with in the form of pyrites disseminated through the mass.

337. According to Vauquelin, the meteoric stones of *Ville Franche* of 1798, contain silica 46, oxide of iron 38, magnesia

[1] New Month. Mag. 1814, vol. i. p. 425.

15, nickel 2, lime 2; = 103,—the excess of 3$\frac{0}{0}$ being ascribed to the absorption of oxygen by the iron during the analysis. The Aigle meteorolites of 1808, were ascertained to contain silica 53, oxide of iron 36, magnesia 9, nickel 3, sulphur 2, lime 1; = 104,—the excess of 4$\frac{0}{0}$ arose probably during manipulation. The *Bavarian Meteorolite* of 1803, furnished metallic iron 18, brown oxide of iron 25.4, nickel 13.5, magnesia 32.5, silica 10, sulphur 0.6; = 100. The *Apt* stone of 1804, yielded silica 34.0, magnesia 14.5, iron 38.03, nickel 0.33, manganese 0.83, sulphur 9.0; = 96.69. Vauquelin found in the *Alais aëorlite* of 1806, silica 30, magnesia 11, iron 38, nickel 2, manganese 2, sulphur 1, chrome 2.5, and carbon a trace. Warden obtained from the *Weston meteorolite* of 1807, silica 41, alumina 1, lime 3, magnesia 16, oxide of iron 30, manganese 1.34, sulphur 2.33, chrome 2.33; = 97. Vauquelin found in the *Charsonville stone* of 1810, silica 38.4, alumina 3.6, lime 4.2, magnesia 13.6, iron 25.8, nickel 6, manganese 0.6, sulphur 5, chrome 1.5; = 98.7. That at *Chassigny* yielded him silica 33.9, oxide of iron 31, magnesia 82, chrome 2; = 98.9. Laugier found in the *Jonzac aërolite* of 1819, oxide of iron 36.0, silica 46.0, alumina 6.0, lime 7.5, oxide of manganese 2.8, magnesia 1.6, sulphur 1.5, chrome 1.0; = 102.4. The *Courland meteorolite* of 1820, was found by Grotthus to yield iron 26, nickel 2.0, sulphur 3.5, silica 33.2, protoxide of iron 22.0, magnesia 10.8, alumina 1.3, chrome 6.7, lime 0.5, manganese a trace; = 100. Stromeyer found in the *Köstritz stone* of 1820, silica 38.05, magnesia 29.93, alumina 3.46, protoxide of iron 4.89, oxide of manganese 1.15, oxide of chromium 0.13; = 77.61, + iron 17.48, nickel 1.36, sulphur 2.69; = 99.14. The *Maine meteorolite* of 1823, yielded Dr Webster sulphur 18.3, silex 29.5, alumina 4.7, lime a trace, magnesia 24.8, chrome 4.0, iron 14.9, nickel 2.3; = 98.5. The *Maryland aërolite* of 1825, yielded an unmagnetical and a magnetical portion; 25 grains of the former furnished Mr Chilton with silica 14.9, magnesia 2.6, lime 0.45, oxide of iron 6.15, oxide of nickel 0.8, sulphur 1.27, alumina 0.05; = 26.22; the same quantity of the latter produced oxide of iron 24, oxide of nickel 1.25, silica and other earthy matter 3.46, sulphur a trace; = 28.71. The *Concord*

aërolite of 1840, contained silica 84.973, magnesia 12.076, soda 2.218, loss and hygrometric moisture 0.233 ;=100. Laugier[1] states, that he has detected chrome in meteoric stones from Verona, Barbotan, Ensisham, L'Aigle, and Apt, in the proportion of about 1$\frac{0}{0}$.

According to Proust and Klaproth, *meteoric iron* differs from that ordinarily met with in the presence of nickel, and John found that the iron of aërolites does not contain so much of that metal as the great malleable masses. Dr John also found that the iron of meteorolites, and the malleable iron in large masses, contain the same substances, viz. iron, nickel, cobalt, chrome, and perhaps a trace of manganese, which he discovered in the iron of *Ellbogen*, in Bohemia. The *Siberian mass* has 98.5$\frac{0}{0}$ of metallic iron, and 1.5$\frac{0}{0}$ of nickel,—Klaproth; the *Agram mass*, 3.5$\frac{0}{0}$ of nickel,—Klaproth; the *Mexican*, 3.25$\frac{0}{0}$; and that from the *Sahara*, 4$\frac{0}{0}$ of the same metal,—Howard. From the *South American mass*, Proust obtained 50$\frac{0}{0}$ of sulphuret of nickel, and Howard and Count de Bournon corroborate this result. Turner found the *Atacama mass* in Chili to consist of iron 93.4, nickel 6.62, cobalt 0.53;=100.55. Stromeyer detected cobalt in a specimen from the Cape of Good Hope.

The gem *chrysolite,—Peridot*, Haüy, *Olivine*, Werner,—which occurs chiefly in secondary trap, is frequently met with in meteoric stones. This mineral, from aërolites analysed by Stromeyer, contains silica 38.18$\frac{0}{0}$, magnesia 48.82, oxide of iron 11.19, and nickel a trace;=98.19.[2] Rose[3] of Berlin found in the Juvenas aërolite well-marked crystals of Augite ;[4] the same specimen appeared to contain Albite or Soda-Felspar.[5] These minerals are all of them met with in the neighbourhood of Edinburgh.

338. Various conjectures have been hazarded on this *questio vexata*, and explanations of the origin of meteoric stones proposed; these resolve themselves into one or other of the four theories, the terrestrial, atmospheric, lunar, and cosmical.

Those who explain their origin by the first of these hypo-

[1] Annal. de Chimie, tom. lviii. [2] Jameson's Mineralogy.
[3] Ed. Phil. Jour. [4] Haüy's Mineralogy, fig. 109. [5] Cleavelandite.

theses, call in the agency of volcanoes, or the influence of lightning in tearing up the ground and transporting to a distance. We grant the power of such forces in some of the instances, but we discard the theory, on the ground that as the chemical composition of aërolites is altogether different from that of terrestrial bodies, they are not telluric, and the similarity referred to, indicates for nearly all a common origin. Lemery, Muschenbröck in one part of his writings, and Bory de St Vincent[1] support the terrestrial theory, but they are not agreed as to the mode by which the projection takes place: the speculation of the last of these philosophers is almost a satire.

339. The *atmospheric hypothesis* has greater weight of authority than either the terrestrial or lunar, and certainly is much more tenable than either, but to us it does not seem satisfactory. From the fact that mineral and gaseous particles are constantly floating in the air, it has occurred to the supporters of this theory, that these, meeting—perhaps through the agency of electricity or chemical affinity,—become consolidated and fall to the earth. It is believed by the partizans of the atmospheric theory, that all ponderable bodies are constantly parting with particles from their surfaces by a process of evaporation, besides those which are separated by other causes, a theory denied by Faraday[2] on the principles of gravitation, cohesion, and elastic tension. Some of the attending phenomena, are certainly most easily explained by this hypothesis, and we can conceive of such an origin in the case of minute aërolites, but how upon these principles to account for the formation of those enormous masses which have been recorded, is to us a matter of exceeding great difficulty. It reminds us of an exploded theory of the presence of marine shells far above the sea level, as, for example, on the top of Snowdon, that they had been left there by way-worn pilgrims, or dropped by birds after feeding on their contents,—a cause rejected upon its inadequacy. Patrin, Muschenbröck, Izarn, Salverte, Ideler, Egen, Fischer, Jameson, and others, support this theory.

[1] Voy. dans Princip. Isles des Mers d'Afrique.

[2] Phil. Trans. 1826,—On the existence of a limit to vaporization.

340. The *lunar theory* is the offspring of the fertile mind of the Marquis de Laplace, though suggested about a century before his birth, by an Italian. This great astronomer brought the science of numbers to bear upon the question, and demonstrated the possibility of a projectile reaching our globe—having received a certain initial velocity—from a lunar volcano. It is evident that there does exist between our globe and her satellite, a point where the attraction of each is equal, beyond which, a body will fall either to the earth or the moon. Laplace has calculated that a force equal to that of about 10,000 feet *per second*, or an initial velocity not quite four times more rapid than a cannon-ball, will carry a body from the moon beyond *that* limit and thus determine it to the earth's surface. Olbers, Biot, and the late Baron Poisson arrived at a similar conclusion, and Izarn[1] has given the algebraical calculation. Before this hypothesis can be assumed, it must be demonstrated that an atmosphere surrounds that luminary, for unless nature has other laws to direct her operations in our satellite than here, no projectile could be thrown from a volcano without an atmosphere to furnish oxygen to feed the flame. We had hoped that the existence of such an aërial body would have been shewn by the magnificent telescope of Lord Rosse, but the appearance of her disc through that powerful instrument, affords no indication of the presence of air similar to ours; besides, the "volcanoes," several of which are miles in breadth, are all extinct! In the year 1820, Laplace abandoned this theory, and adopted that which gives them a more distant origin.[2]

341. The last hypothesis is that which supposes these bodies to be *cosmical*. Chladni, Humboldt, Halley, Bergman, Brewster, and many others, have adopted it. According to this theory, aërolites are supposed to have an existence independent of other celestial bodies, revolving with the planets in infinite numbers, and similarly produced, or to be fragments of a great planet of which the minor planets are the

[1] Lithologie Atmosphérique.

[2] Paper read before Fr. Board of Long. 29th March 1820; Ed. Phil. Jour. vol. iii. p. 197.

representatives. That these bodies were once united is highly probable, not only from their almost equidistance from the sun, and their diminutive size, but from the eccentricity of their orbits; for Olbers remarked, that upon that supposition, the orbits having all diverged from one point, so must the fragments have their parhelia in the same part of the heavens, and their aphelia in the opposite celestial hemisphere, in other words, they must have two common points of reunion in the course of their periodic revolution—and it is so. Besides the arguments of projection and velocity, which flow as a consequence of such a catastrophe, in favour of this origin of these bodies, their specific gravity supports this theory, as has been pointed out by Brewster.[1] Upon this hypothesis,—and it is the only one we consider ourselves warranted to adopt—these meteoric bodies assume no small importance. If the fossils of our globe bear record of changes in the abode of man, primeval to the historic era, these aërolites testify to some catastrophe in the planetary regions. If the "Medals of Creation" shew that the grand principles of life have been unchanged, the meteorolites plainly tell us they are the product of familiar elements—they convey the striking declaration that the *matériel* of the universe is the same! The celestial origin of meteorolites was taught by Diogenes of Apollonia, about 500 years before the Christian era; nor do we wonder, for Diogenes was a disciple of Anaximenes, who seeking for a *first principle* of matter,—a favourite speculation with the ancients—placed it in air, which he considered to be infinite, and thus improved the doctrine of Anaximander that infinity was the universal element.

342. *Asteroids*, Falling or shooting stars, resemble the bolis in miniature. They are visible at all seasons, but most frequently in the winter and during the occurrence of the aurora borealis, which on these occasions has been remarked to be peculiarly brilliant. Not only do they flash across the sky, solitary visitors (sporadically), but occasionally in such numbers as to be aptly likened to a shower of fire. Attention has recently been drawn to their periodical appearance by Olm-

[1] Ed. Encyc. ii. 643.

sted, Palmer, Ellicott, and Humboldt, in the month of November; and by Muschenbröck, Olbers, Quetelet, Benzenberg, and Arago, in the month of August. The general direction of these bodies is contrary to that of the earth's orbit; and their velocity about twenty-five miles in a second, or nearly as rapid as that of Mercury. They have been viewed by some as electrical phenomena, and by Sir Humphrey Davy and Chladni as very minute meteorolites, but the most generally received opinion is, that they are small asteroids—hence the name—revolving round the sun, coming at certain seasons within the reach of the earth's attraction and igniting in her atmosphere,[1] or as Poisson[2] thought, far beyond the atmosphere. A recent speculation of Sir J. Lubbock[3] is worthy of attention, although a sufficient number of facts are wanting to establish its correctness. To him it appears that these asteroids are cosmical bodies revolving *round the earth* with incredible velocity—flashing "in night's high hall" under the reflecting influence of solar light, and disappearing in the shadow of our globe.

343. Hemmer witnessed, on the night of the 9–10th November 1787, numerous shooting stars at Mannheim in Southern Germany; and on December 6–7th 1798, Brandes enumerated 480 of these meteors. Humboldt[4] mentions a fine display of falling stars, observed by the late M. Bonpland, the companion of his travels, on the 11–12th November 1799, at Cumana. Thousands of these meteors succeeded each other towards morning for a period of four hours; their direction was from N. to S., and they filled a space in the sky of 60° in breadth, the due east being in the central line: a slight easterly wind was blowing at the time. The passage of these meteors was indicated by luminous tracks, which remained visible about eight seconds. Some exploded, but most of them disappeared without scintillations. The atmosphere, before and after, indicated considerable electric excitement; thus, between the 18th October and 3d November, a reddish vapour rose at twilight

[1] Annuaire pour l'année 1836; Professor Olmsted,—Sillman's Jour.
[2] Rech. sur la Probabil. des Jugements, 1837, p. 6. [3] Phil. Mag.
[4] Relat. Hist. Voy. dans les Rég. Equinox. tom. i. pp. 519, 527.

and diffused itself over the sky—the grateful breezes no longer cooled the air—the hygrometer shewed no indication of humidity—the ground cracked and was everywhere dusty. As the season advanced, the fog thickened, and large black clouds obscured the heavens—the heat was stifling, but the thermometer did not indicate a temperature corresponding to the sensation,—it was 78°.8. Upon the 4th of November, about 4 P.M., thunder growled overhead, at a great altitude—its roar was interrupted. At a quarter after four o'clock, two shocks of an earthquake, separated by an interval of fifteen seconds, were felt. M. Bonpland, engaged in his botanical pursuits, was thrown on the floor, and the Baron Alexander von Humboldt was strongly concussed in his hammock. The terror of the people vented itself in agonizing cries; they collected in the public square of Cumana, fearing that their city should be destroyed. The wind, which blew in gusts immediately before the earthquake, and the rain which accompanied it, now ceased, and the rain drops were dried up. The sun set that day in magic splendour. The dark veil was rent at the horizon and exposed to view his disc, enormously enlarged and distorted, upon an indigo ground—his rays gilded the edges of the clouds and were dispersed over the sky, reflecting vivid and brilliant prismatic hues. About 9 P.M., another earthquake was felt, though slighter, attended with a subterranean sound. The magnetic needle sympathized with the motion. The sky became serene and clear upon the 7th, and four nights thereafter, this fine display of meteors took place, regarding which, Humboldt obtained from other observers some interesting facts. Thus, at Cumana, in lat. 10° 27′ 52″ and long. 66° 30′, they were visible from 2–6 A.M., at an elevation of 40°, and their course was E. and E.N.E.; at Porto Cabello, in lat. 10° 6′ and long. 67° 5′, and at the frontiers of Brazil, near the equator, in W. long. 70°, the same meteors were seen. The Count de Marbois observed them in French Guiana, in lat. 4° 56′, and long. 54° 35′; Ellicott[1] saw the same in the Gulf of Florida, and the phenomenon was perceived in America in lat. 30° 42′. They were witnessed in Labrador,

[1] Tr. Amer. Soc. 1804, vol. vi. p. 29.

and they excited alarm in Greenland. Zeissing saw them near to Weimar, in Germany, in lat. 50° 59′, and long. 9°. From these observations, their altitude has been computed at the amazing height of 1419 miles. At Weimar, their path was in the S. and S.W., consequently they passed between that place and Cumana, and fell, in all probability, into the Atlantic Ocean, to the west of the Cape de Verd Islands.

Shooting stars were noticed upon the 8th November 1813, and 13th of the same month 1818, in England ; on the 12–13th November 1823, at Potsdam, according to Klöden ; on the 13th November 1831, in Ohio, and off the coast of Spain ; and in 1832, over all Europe, at Mocha by Captain Hammond, and even at the Isle of France by M. L. Robert. Professor Olmsted, of Yale College, describes the appearance of these meteors in America, on the 12th November 1833, when they were visible for several hours,—it is computed that about 240,000 fell on that occasion, and they were seen from the coast of Halifax to the Gulf of Mexico.[1] All of them came from the same quarter of the heaven,[2] viz. γ *Leonis Majoris*, preserving their position during the period of observation, regardless of the changes in the declination and azimuthal distance of that star. So brilliant was this display, that Olbers[3] the astronomer, believing them to be the same witnessed at Cumana in 1799, predicts their return in 1867. In November 1834, Olmsted, accompanied by a number of college friends and students, watched the appearance of the asteroids. About 3 A.M. of the 13th, they were seen, in all respects the same as those of the preceding year, but not so numerous ; their centre of origin was again in *Leo Major*. A splendid fire-ball heralded their approach, and before dawn, at least a thousand fell, though, owing to moonlight, this was perhaps below the actual number. Upon the 12–13th November 1836, it is mentioned by Arago, that 170 were counted from the Observatoire at Paris. In November 1837, the phenomenon was again witnessed, the meteors preserving a striking parallelism in their direction. In November 1838, during an ob-

[1] Naut. Mag. No. 29,—Barnet. [2] Encke,—Pog. Annal. 1834.
[3] Schumacher's Jahrbuch, 1837, s. 280.

servation of six hours' continuance, M. Karl von Littrow enumerated 1002 of these meteors, viz.,—32 during the first hour, 52 during the second, 70 during the third, and 157, 381, and 310, during the others respectively. On the night of the 12–13th of that month, Mr Woods, who watched their appearance at Richmond in Surrey, computed the number at 500. According to Professor Encke, the point in planetary space whence these meteors issued, was the goal of the earth's motion at the same epoch.

344. The attention of meteorologists having been turned to this interesting theme, it was noticed that the periodical return of the phenomenon was not confined to the month of November, but that August had its recurring showers of "fiery tears." Forster[1] mentions the interesting circumstance, that in a MS. in Christ's College, Cambridge,[2] supposed to be the production of a monk, there occurs opposite to the 10th of August, the word *meteorodes.* Muschenbröck[3] was the first to observe the autumnal display of falling stars ; and since the last century their frequency and certain return between the 9–14th of August—about the *feast of St Lawrence*—has been pointed out by Quetelet,[4] Olbers, Benzenberg, Erman,[5] Arago, and Humboldt.[6]

Sir William Hamilton,[7] describing the eruption of Vesuvius, in August 1779, observes,—"August 9. 1799, when all was calm, it was universally remarked that the air, for many hours after the eruption, was filled with meteors, such as are vulgarly called falling stars." The simultaneous appearance of these meteors and a volcanic eruption, was in this case merely a coincidence. Mr Luke Howard[8] records, that on the 11th August 1813, "small scintillant meteors now appeared, falling almost directly down, and seeming to originate very low in the atmosphere ;" this observation of their altitude was probably an optical illusion. Dr Burney[9] enumerates eighty of these asteroids in August 1820, while only sixteen appeared

[1] Pocket Encyc. Nat. Phil. 1827, p. 17. [2] Ephemerides Rer. Naturalium.
[3] Introduct. Nat. Phil. ii. 1061. [4] Correspond. Mathématique, 1837.
[5] Schumacher's Jahrb. 1838. [6] Cosmos,—Sabine, vol. i.
[7] Tr. Roy. Soc. vol. lxx. [8] Ann. of Philos. ii. 240. [9] Ib. xvii. 365.

during the two previous months, and fourteen in those of September and October. In August 1837, the periodical return of the phenomenon was sustained ; from $11^h 15^m$ to $12^h 15^m$ on the 10–11th of that month, MM. Bouvard and Laugier counted 184, the greater proportion of them falling towards *Taurus.*[1] These meteors were again seen in August 1838, both on the continent and in America,[2] where Professor Silliman considered them above average. The year 1839 afforded a striking display, with this peculiarity, that they proceeded from a spot between *Taurus* and *Perseus*, and not in *Leo*, as in the winter visitations. These meteors were seen in China by Dr Parker of Canton, who observed 64 on the 10th, and 404 on the 11–12th, between $8^h 15^m$ and $4^h 30^m$ Those of August 9. 1840, emanated, according to Sir John Herschel, from γ *Pers.* as in the former year. On August 9–10th 1841, many were seen both here and in America. In 1842, these "fiery tears" were showered upon us: during the night of the 10–11th, MM. Bouvard and Petit observed them at Paris and at Tour, and in the Department of the Doubs. At Vienna, M. Littrow counted 129 per hour, but at Rennes, only 44 per hour were enumerated. M. Bordot of Grand Temps in the Isère, in a communication to the Academy of Sciences, stated, that he observed the appearance of these meteors on the night of the 11th, and that when they exploded, in *no* case was sound perceptible, but in many instances there followed a train of phosphoric light.[3] On the 9–10th August 1844, they appeared at Bruges, without intermission, averaging 96 per hour ; the point of convergence was in a spot near *Antares* and *Scorpio.* On the 7th August 1845, a shower of asteroids was seen from Liverpool ; and on the 9–10th of that month, 517 were numbered by an observer on the continent. In August 1846, these meteors were again seen. We find the following interesting record of these meteors in Holinshed :[4]— "In the night of the six and twentieth of Julie 1242 [old style] starres were seene, fall from the skie after a marvellous sort, not after the common manner, but 30 or 40 at once, so fast

[1] Compt. Rend. Aug. 1837, p. 184; Phil. Mag. No. 73.
[2] Silliman's Jour. No. 71. [3] Athen. No. 777. [4] Chron. vol. iii. p. 231.

one after another, and glancing to and fro, that if there had fallen so manie verie starres indeed, there would none have been left in the firmament!" Von Hammer quotes visitations from Soyorite,[1] in the year 1029, in the month Redjib or August. In the fifteenth century, a fall of shooting-stars took place in the same month.

345. It is conjectured by Humboldt, and believed by Olbers, that the epochs of the asteroids are falling later in the year in consequence of retrogression of the nodes of their orbit from planetary disturbances; and this view harmonizes with the records of antiquity. Thus, Humboldt[2] instances from the Chinese Annals, two showers in March, one of which took place 687 years B.C.; and on the authority of Biot,[3] the period of most frequent occurrence of fifty-two recorded observations by the Chinese, was from the 20th to the 22d July, *old style.* The quotation from Holinshed supports this view. Humboldt[2] records a shower which was visible in day-light, on the 21st October 1366, *old style,* "intanta multitudine quod nemo narrare sufficit;"[4] and M. Von Hammer has reported to the French Academy of Sciences the following appearances:—In October 902 of our era, "on the night of the death of King Ibrahim-ben-Ahmed, an infinite number of falling-stars were seen to spread themselves like rain over the heavens, from right to left:"[5] on the authority of Soyorite,[1] he instances a fall on the 19th October 1202 of our era—or on Saturday night, in the last Moharrem of the year 599—"the stars appeared like waves upon the sky towards the east and west; they flew about like grasshoppers, and were dispersed from right to left; this lasted till daybreak; the people were alarmed." The chronology of Hadje Calfa mentions the occurrence of this phenomenon on the night preceding the last day of the month Moharrem. In the tenth century a shower was observed in April.

346. Humboldt[6] observes, that probably farther observation

[1] Hist. of Cairo. [2] Cosmos, vol. i. pp. 118, 382.

[3] Lettre de M. Ed. Biot. à M. Quetelet, sur les appar. d'étoiles filantes en Chine, —Bul. de l'Acad. de Bruxelles, 1843, tom. x. p. 8.

[4] Chron. Ecclesiæ Pragensis, p. 389; Pog. Annal. xlviii. 612.

[5] Condé,—Hist. de los Arabes, 346. [6] Cosmos, vol. i. pp. 115, 387.

will shew a periodical recurrence of this phenomenon from the 22–25th April, the 6–12th December, the 27–29th November, and about the 17th of July, besides the other epochs.[1] In corroboration, he instances the recorded showers of shooting-stars of the 25th April 1095, mentioned in the Council of Clermont,—in France, they fell " as thick as hail ;[2]—that of the 22d April 1800, in North America ; that of the 6–7th of December 1798, by Brandes ; that of the 11th December 1836, at Macao in Brazil ; and those mentioned by Capocci, between the 27–29th November, and 17th of July. The same learned and accurate observer, thus eloquently reviews the falling of an asteroid :—" The profound repose of night is suddenly interrupted, and life and motion momentarily break the tranquil splendour of the firmament. The spectator sees in the glimmering light which marks the track of the falling-star, the visible delineation of a portion of its orbit ; and the burning asteroid brings to his mind the existence of matter pervading universal space. When we compare the volume of the innermost of Saturn's satellites, or of Ceres, with the enormous volume of the sun, the relations of great and small disappear to our imagination. The sudden blazing up and subsequent extinction of stars in Cassiopeia, Cygnus, and Ophiucus, have already led to the admission of the possible existence of non-luminous cosmical bodies. Condensed in smaller masses, the asteroids revolve around the sun, intersect like comets the paths of the great luminous planets, and become ignited when they enter or approach the outermost strata of our atmosphere."[3]

347. We would not close this section without briefly referring to a curious, but as yet mystic connection between the epochs of these meteors and certain remarkable obscurations of the sun, observed in olden times. Virgil[4] mentions a preternatural darkness as one of the prodigies accompanying Cæsar's death—which, however, might have been an eclipse:—

[1] Comptes Rend. tom. ii. p. 357.

[2] Chron. of Baldric, Leipsic, 1807; Athen. No. 466, p. 708, Oct. 1836.

[3] Cosmos, vol. i. p. 125.

[4] Geog. lib. i. v. 465; vide Pliny, Hist. Nat. lib. ii. cap. 33; Tibullus, lib. ii. 5; Lucan,—Pharsal. lib. i.

"Ille etiam exstincto miseratus Cæsare Romam,
Quum caput obscura nitidum ferrugine texit,
Impiaque æternam timuerunt sæcula noctem."

"He first the fate of Cæsar did fortell
And pitied Rome, when Rome in Cæsar fell;
In iron clouds conceal'd the public light
And impious mortals fear'd eternal night."
DRYDEN.

Temporary darknesses have been occasionally recorded, one of the most striking of which, both for intensity and duration, occurred in 1547,—a year memorable for the battles of Mühlberg on the 24th of April, at Pinkie on the 10th September, and not to be forgotten, as already observed, for blood-spots in Germany. On the 17th June 1777, Messier observed for about five minutes at noon, a very large number of black globules cross the sun's disc. We instance this observation because of its importance in aiding the conjectures regarding these temporary darknesses, that they have arisen from the interposition of bodies between the sun and the earth. The 11–13th May have been described as *cold days.* Kepler sought the cause of the phenomenon, in solar emanations; Chladni explained it by the interposition of meteoric bodies; and to Professor Erman[1] it seems owing to the transit of the asteroids which we have described. If we suppose that these bodies revolve round the sun in a very eccentric ellipse, cutting the orbit of the earth in two parts of its circumference like Biela's comet, and performing their solar revolution in the same time as our globe, their conjunction will take place when the earth has completed one half of its revolution, and thus the phenomenon of showers of fire and cold days, periodically recurring, will be explained. The conjunction of the November meteors with the sun and the period of the cold days recorded, is a coincidence almost warranting this explanation, and connecting them by cause and effect. But we are not limited to the belief that only *one* group of asteroids exists. We have several *minor* planets revolving in orbits *sui-generis*,[2] and certain comets bearing a closer connexion with

[1] Pog. Annal. 1839.

[2] The eccentricity in parts of the semi-axis of Vesta = 0.0891; Juno = 0.2578; Ceres = 0.0784; Pallas = 0.2416; Astræa = 0.195.

ourselves than any of the others.[1] May we not have more than one cluster of asteroids, similar, yet independent, subject to perturbations by telluric and atmospheric influences?

348. May not the passage of such bodies also explain the well-known fact, that though our atmosphere may seem equally clear, the moon does not always shine with uniform lustre? We know that the comet of 1770, whose path was calculated by Lexell, and subsequently by Burkhardt,[2] passed in 1767 and 1779, between Jupiter and his satellites, and was drawn from a parabolic curve to an ellipse and then thrown by their attractions into a different orbit. Float on, thou wandering mystery, in the chill depths of infinity, for thou art no longer ours! Astonish another world with thy spectral appearance, but return to tell us of thy destiny. We may be sleeping with our sires, but a new generation rejoicing in their youth, will hail thee from afar, and welcome thy presence in their fathers' sky! But, perchance, thou art revolving with thy great disturber, and adding thy feeble light to his already gorgeous night-vault. How strange if true![3] Is it unphilosophical to suppose that meteors occasionally pass between our earth and moon, and thus eclipse a portion of her clear cold beams? We venture this suggestively, for nevertheless some beautiful, and as yet unaccountable phenomena attending the occultation of stars by our statellite, it is doubtful, we had almost said *certain*, that that body has no atmosphere like ours—

To dim, by flitting clouds her silvery light.

[1] The eccentricity of the orbits of the comet of Biela = 0.751; of Encke = 0.845; of Faye = 0.551.

[2] Mém. de l'Inst. 1806.

[3] Since writing this we have read the following note by Sir David Brewster:— "Our astronomical readers will be gratified to learn that M. Leverrier has found that the periodical comets of 1770 and 1844 are two different bodies; that two of the comets of Faye, Vico, and Lexell, passed close to Jupiter; and that all these comets, now permanently attached to our system, have come into it and been detained by the action of Jupiter and other bodies. M. Leverrier proves that the comets of Faye and Lexell have been in our system for at least a century, and have come a dozen of times near the earth without being observed. The comet of 1844 he proves to be the same as that of 1678, which has travelled into our system from the depths of infinite space, and been fixed among us centuries ago. It will revisit us in 1849."—North Br. Rev. No. xvi. p. 51, note, Feb. 1848.

CHAPTER XIV.

349. Aurora borealis. 350. General appearances. 351. Examples. 352. Features at the Bay of Alten. 353. Appearances during present century. 354. Visible over great extent. 355. Aurora australis. 356. Corona borealis. 357. Fixed order of progression of the Polar Lights,—dark segment, arc, rays, wreath. 358. Hues, and Lustre. 359. Height. 360. Periodicity,—secular, mensual, diurnal. 361. Magnetic influence. 362. Magnetic storms. 363. Odour,—*ozone*. 364. Sound. 365. Hypotheses. 366. Magnetic theory. 367. Zodiacal light. 368. Cause. 369. Ignis Fatuus. 370. Appearances. 371. Luminous appearances unconnected with evolution of heat. 372. Cause of the Ignis Fatuus; Sepulchral lamps.

> "In Fancy's eye encount'ring armies glare
> And sanguine ensigns wave unfurl'd in air!
> Hence the deep vulgar deem impending fate,
> A monarch ruined or unpeopled state."
>
> SAVAGE.

349. The *aurora borealis*, or polar lights, is one of those beautiful luminous meteors which in all ages since its first appearance, has attracted notice, and names, fanciful as numerous, have been applied to it. It is the *nordlichter* or *nordscheine* of the Germans, the *merry-dancers* of the Shetlanders, and the *streamers* of others, associated in the minds of the vulgar, who inherit by descent the opinions of their ancestors, with all that is terrible and portentous. To the ancients it was known according to its peculiar appearance by the names of *trabes*, *bolides*, *chasmata*, *capra-saltans* or skipping goats, and when the beams resembled the staves of a cask, *pithias*. Flying dragons, hostile armies, and other signs and prodigies have been traced by the superstitious, in the *bloody rods* and *burning spears* of the aurora, no difficulty being found in accommodating the modes of celestial warfare

to the ideas of the beholders and the times. The untutored Indian views in it, the spirits of his fathers roaming in the land of souls.

350. The aurora borealis is a luminous meteor of much beauty, appearing in the northern sky, seldom stationary, often flitting about with great velocity, or breaking out in fantastic corruscations. Sometimes it spans the earth, enclosing in its arc, a gloomy segment through which the stars may be observed—this was termed by the ancients Bothynoë, a cave or chasm, and is mentioned by Aristotle. At other times, it appears in concentric arcs; and sometimes assumes the form of nebulous or curdled masses, or bands. In hue and shade there is no little variety, from a smoky-black, or a steel-grey, to a deep yellow; from a violet to an orange, or from a russet-brown to a fiery red. So vivid occasionally is this meteor, that it was seen by day on the 29th January 1786, by Lowenorn, and subsequently by Sir W. E. Parry.[1] The aurora borealis is most brilliantly exhibited in the polar regions, enlivening the long absence of sun, and aided by the protracted twilight, enabling the inhabitants of those dreary climes to engage in occasional pursuits, so that—

> "Even in the depth of polar night they find
> A wond'rous day; enough to light the chase,
> Or guide their daring steps to Finland-fairs."
> THOMSON,—*Winter*, v. 863.

351. The aurora borealis[2] has been described by Aristotle,[3] and referred to by Pliny,[4] Seneca,[5] and others. Frobesius[6] records appearances of this meteor in the years 502, 465, and 463 before the Christian era, beside many others down to modern times. Holinshed[7] mentions several undoubted appearances in England, in the years 1194, 1204, 1564, 1574, and 1575; Stow notices those of 7th October 1564, and 14th and 15th November 1574; the latter is mentioned by Camden. Halley[8]

[1] Jour. of Voy. 1821-23, p. 156.

[2] For notices of this meteor in the Phil. Trans. of last cent., see vols. for the years 1716, 1717, 1719-24, 1726-31, 1734, 1736, 1740, 1741, 1750, 1751, 1762, 1764, 1767, 1769, 1770, 1774, 1781, and 1790.

[3] Meteors, book i. ch. iv. v.

[4] Nat. Hist. ii. 27, 33.

[5] Quæst. Nat. lib. i. cap. 15.

[6] Cat. pub. at Helmstadt, 1739.

[7] Chron. vol. iii. pp. 143, 166, 1207, 1260, 1261.

[8] Ph. Tr. No, 347, p. 406.

quotes its appearance on the 30th January 1560 at London.[1] Those of 1575 were seen in Brabant, and have been described by Gemma of Louvain. In 1580, Mæstlin of Tubingen, the preceptor of Kepler, witnessed the polar lights seven times, at Baknang, in Wurtemberg;[2] in the following year they were seen several times, but particularly in February and September. On the 13th and 15th September 1606—the day before and after the royal baptism at Fontainbleau, where the court of Henry IV. of France were assembled,—the aurora borealis appeared, and continued to excite fears till the *savans* of those days agreed among themselves that the apparitions were only exhalations! It was upon the appearance of this meteor, on the 2d September 1621, that Gassendi gave it the name *aurora borealis.* In November 1623, an appearance of the polar lights in Germany, is noticed by Kepler. Cotes notices that one which was seen at Cambridge, on the 20th November 1706. It was observed in 1707 in Ireland;[3] and was witnessed the same year[4] by Romer at Copenhagen, and Kirch at Berlin; in 1708 it was seen at London by the Bishop of Hereford; and in 1710, at Leeds, by Thoresby.[5] Halley[6] says he waited till he almost ceased to hope, before he was gratified with the spectacle—at last, on the 6th March 1716, an aurora borealis of great beauty appeared, and attracted general attention: it was visible from the west of Ireland to the confines of Russia. It became the theme of the vulgar, and though our illustrious Hanoverian kings had began to reign two years before, that was no objection in their minds to its connection with the new dynasty. Several other appearances are recorded between that year and 1723, when the phenomenon was seen at Bologna. On the 19th October 1726, a very singular one was witnessed at Breuillepont in Normandy, and figured by Mairan.[7] In November 1765, the whole horizon in the lat. of 57° was overspread with a red aurora. Maupertuis saw one at Oswer Zornea, very vivid and forming a

[1] A Descrip. of Meteors by W. F.—D. D. Lond. 1654.
[2] Lib. de Cometa, 1580.
[3] Neve,—Ph. Tr. No. 320; Abr. ii. 112–123.
[4] Miscellanea Berolinensia, 1710.
[5] Phil. Tr. No. 331, p. 322; Abr. ii. 114.
[6] Ib. No. 347; see also Nos. 351, 352,—Aur. observ. by Barrel and Foulkes.
[7] Traité dé l'Aur. Boréale, 1754.

dome round the zenith; it was remarkable for its deep red colour, which caused Orion to look at one time as if dipped in blood. A fine meteor of this kind was witnessed in France and in Pennsylvania, on the 5th January 1769. Celsius observes that this meteor was considered rare in Sweden previous to 1716, though between the years 1706 and 1732, he has collected 316 observations of it in that country. M. de Mairan catalogues 1441 appearances between the years 583 and 1751, including 2137 observations. Doubtless the records of many are wanting, or there must have been a remarkable absence of the phenomena in the 17th and early part of the 18th centuries.

352. During the present century the appearances of this meteor have been both numerous and grand. The members of the French Commission, viz., MM. Lottin,[1] Bravais, Lilliehook, and Siljestrœm, who wintered at Alten Bay, in West Finmark, observed 150 displays during a period of 218 days, from the 12th September 1838, to the 18th April 1839. Some of these were truly splendid—at one time the meteor was seen, as if hanging in graceful festoons, at another, like a flag waving in the breeze, then the beams would curl up most gracefully and suddenly become extinguished or slowly die away; during these changes, the hues were no less remarkable, for the beams, which were beautifully transparent and of great brilliancy, assumed the colours of the ruby, emerald, and topaz. To such a spectacle an indescribable charm was added by the physical peculiarities of the locality; the ground as far as the eye could reach was dazzlingly white with snow, while the bay, the surface of which was "dark as Erebus," partook of the general repose.

353. Sir John Franklin[2] records some interesting observations made upon the aurora borealis at Cumberland House and Fort Enterprise, in North America, by himself, Sir John Richardson, and Lieutenant Hood, to which we shall again refer. But to come nearer home:—

A fine aurora borealis, remarkable for its luminous arc,

[1] Compt. Rend. tom. x. p. 289; Lard. and Walker,—Elect. and Met. vol. ii. p. 225.
[2] Nar. of Jour. to Shores of Polar Sea, 1819–1822. Appendix, 4to.

was seen here on the 11th September 1814[1]. In Scotland, it was witnessed at Forfar, Perth, Edinburgh, Glasgow, Annan, and Dumfries; in England, it was observed at Carlisle, Kendal, Lancaster, Warrington, and Liverpool; and in Ireland, at Newry, and Dublin. On the 19th of March 1825, a magnificent aurora was seen at Edinburgh; about ten o'clock a fine arch crossed the zenith, through which stars of the 1st and 2d magnitude only could be seen. At Paris, the magnetic needle was that day greatly agitated.[2] Upon the 25th of September 1827, one was seen which has been described by Mr Kendall.[3] An auroral arch of great beauty was seen at Edinburgh on the 15th September 1828: at 9^h 17^m it passed through *α Lyræ* and *α Cassiopeiæ*; its direction was E. 23° N. and W. 24° S., at right angles to the magnetic meridian, and at that hour it was in the zenith. At Islay, the aurora in the S.E. part of the horizon was rose-coloured, yellow, and pale green successively[4] On the 29th of the same month another fine arch appeared.[5] A gorgeous display of this meteor took place on the 7th of January 1831, which was seen not only in this country, but on the continent and America.[6] In the afternoon of that day a peculiar brightness near the horizon, for several degrees on either side the polar meridian, indicating the approach of the aurora, was seen at Gosport Observatory. The sun then shone brightly in a cloudless sky. Shortly after sunset the meteor gradually rose above the northern horizon, and at a quarter after five, it assumed the form of an arc of refulgent light, 10° in height and 70° in width; about forty-five minutes afterwards, the arc had expanded so that its chord was 155°. Now a bright flame-coloured rainbow-like arch, between 3° and 4° degrees in breadth, emanated from the curved edge of the aurora to an altitude of 35°; and while

[1] Annals of Philos. iv. 362; Monthly Mag. Dec. 1814.

[2] Ed. Jour. of Sc. vol. v., p. 87; Annal. de Chim. tom. xxx. p. 423.

[3] Quart. Jour. of Sc. 1827, part ii. p. 385.

[4] Ib. vol. x. p. 177,—Forbes; Ib. p. 179.

[5] Ib. vol. x. p 146; Harvey; Ib. x. 177,—Prof. Mole and Capt. Kater; Phil. Mag. N.S. iv. 453,—Gilbert.

[6] Christie, Harris, Mole,—Roy. Inst. Jour. N.S. vol. i.; Sturgeon, at Woolwich,—Phil. Mag. N. S. vol. ix.; Birt, at Isle of Ely,—Drew's Imper. Mag. May 1831. 2d Ser. vol. i., p. 134.

it remained apparently stationary, another arch still more brilliant, formed about 10° S. of the zenith by streamers suddenly springing up from the N.E. by E. and W. by S. points of the horizon, and meeting in the zenith, so that these two bows presented themselves at the same time,—this latter arc soon passed off in long streamers like luminous clouds.

At forty minutes after five, another arch, equally large and bright, was formed by long beams directed from similar parts of the horizon to the same point of convergence. It passed through the constellations Gemini, Taurus, Aries, the square of Pegasus, head of Equuleus, and the bow of Antinous, disappearing towards the south about six o'clock. Half-an-hour thereafter, the aurora, which had sunk considerably, again rose; vivid coruscations darted from its arc, and mingled their crimson tints with one another. By 7.5 P.M. nearly two-thirds of the sky was covered with the polar lights—large columns and short-pointed coruscations rose from the auroral arc perpendicularly and glittered in the sky: the effect was truly grand, for the various tints of orange, rose, lake, crimson, green, and purple, were successively presented. At ten minutes before eight, there was with the double arc a fine display of glowing colours, some of which reached beyond the zenith. Till 2 A.M. it passed through many changes, and gradually disappearing, the observations were discontinued. The magnetic needle was affected towards eleven o'clock, and at midnight a brilliant meteor shot past *Ursa Major*. At the Isle of Ely, two beautiful coronæ of a crimson colour were seen about six and eight o'clock, and towards 7.5 P.M. an appearance was presented similar to that seen by Halley on the 6th of March 1716, and denominated *nebeculæ*.

Mr Sturgeon, who witnessed this magnificent aurora borealis from Woolwich, observes, that the second arc, which appeared about half-past six, and seemed concentric with the first, preserved throughout a distance of about 10°; between nine and ten o'clock the altitude of the superior arc advanced from 20° to nearly 24°, and that of the inner was increased in the same proportion. The *dark segment* was finely seen through the contrast of its dense gloom with the clear atmosphere beyond.

Towards 10 P.M. broad streaks of light sometimes glowed in this foggy-looking area, but they were not frequent. Soon thereafter, "there seemed a steady pause, as if the electrical powers which gave them birth had become partially exhausted. The steady light of the two concentric arches, with a few faint flashes about their edges, were the only traces of the aurora. The cessation, however, was not of long duration ; but the interval gave time for reflection. The night was calm and serene, not a breeze ruffled its repose, nor a cloud curtained any part of the heavens, save that dense dark speck which seemed as a nucleus to the whole display of the aurora borealis ; the atmosphere was cold and frosty, and the stars shone in all their splendour and glory. On turning towards the south, the spectacle presented to the eye was truly grand and imposing, and formed a most beautiful and striking contrast with the phenomena displayed in the north. Taurus had passed the meridian, preceded by the planet Mars; and Orion was now mounting the throne of night ; refulgent Sirius blazed in the S.E. of the stellar train, and enhanced the splendour and solemnity of the scene. In one part of the heavens was displayed the quivering blaze of a transient aurora; in another, the sparkling light and steady march of a transcendent starry host : in the north, a splendid exhibition for the contemplation of the electrician ; in the south, those glorious orbs which are the objects of the astronomer's research."

A very fine aurora was seen at Hull, on the 12th October 1833, described by Fielding.[1] On the 17th November 1835, one was observed by the author at Edinburgh,—its magnificent crimson-coloured beams attracted notice over the kingdom ; another of a similar hue was seen in October 1836, at the same city. One was witnessed on the 18th of that month at Dorpat, by Professor Struve, where the arc rose 90° ; at Caën, by Masson ; at Geneva, by Wartmann, where the altitude of the arc was only 25° ; and at Forli, by Matteucci—this aurora was invisible at Paris in consequence of clouds, but the needle indicated its presence. Dr Allnat[2] describes a blood-red aurora seen at Wallinford on the Thames, on the

[1] Mag. of Nat. Hist. No. 37. [2] Ed. Jour. of Nat. Hist. June 1837, p. 100.

18th February 1837, about 10 P.M.; it formed an irregular arc, with dense luminous patches of a similar colour in the north: it blew from the south at the time, and the next day was wet and gusty. This crimson-coloured auroral arc was visible at the same time at Belfast, and has been described by Professor Stevelly;[1] there, too, the following day was stormy. Professor Christie[2] mentions the occurrence of the aurora borealis in the *summer* of 1837, on the nights of May 19, June 24, from $11^h\ 46^m$ to $12^h\ 20^m$, July 1st, 2d, and 7th, and August 25th. On the 3d September 1839, an aurora borealis was seen at Paris from the Observatory, in Scotland, and in North America. Sir John Herschel[3] mentions one which occurred on the 6th May 1843,—one of the most magnificent meteors which he ever saw. One no less splendid was seen on the 26th of March 1847, at Gainsborough. At 10 P.M. on the 24th of October same year, the writer witnessed a fine blood-coloured aurora borealis in Cheshire. The moon, which was nearly full, tended to diminish the brilliancy of the meteor, nevertheless, the rays could be distinctly traced, radiating, as it were, from the zenith to the horizon in the N.E. and S.W., and appearing, though not constantly, on the western side of the compass between these points. The constellation Auriga particularly, seemed dyed red. This phenomenon was seen in London and other places at the same time;[4] and such was the vigilance of the metropolitan firemen, that upon this, as on other occasions, they set out to extinguish the aurora! A similar blood-red appearance was observed by the author on the 1st of the following month, at the same hour. Again he witnessed a crimson aurora on the night of the 18th October 1848, at 7.75 P.M. *Taurus* was magnificently red. Dr Granville[5] describes this meteor as seen in Russia; Gmelin[6] in Siberia; Bravais and Lottin at Bosekop;[7] and Maupertuis in Iceland, where it seems to be a rare phenomenon—Torfœus, who wrote in Denmark, remembered when, in 1706, it was an object of terror to his countrymen.

[1] Athen. No. 487, p. 142. [2] Ib. No. 518, p. 718; Brit. Assoc. 1837.
[3] Ib. [4] Lond. and Ed. Phil. Mag.; Illust. News, Oct. 30. 1847.
[5] St Petersburgh, 8vo. [6] Blagden,—Ph. Tr. lxxiv.
[7] Elect. and Meteorol. vol. ii. 225,—Lardner and Walker.

354. From the few observations which we have collected in the preceding section, it will be observed, that the aurora borealis is occasionally visible simultaneously, over many degrees both of latitude and longitude. To prescribe a limit beyond which the same meteor shall be invisible, is to set a bound upon its altitude, for the higher the aurora, the more widely will the phenomenon appear. Some interesting records are preserved of the northern-lights having been seen in the southern hemisphere, and as will be mentioned in the sequel, of the southern aurora having been visible in Europe. M. Lafond of the *Candid*, when in the longitude of the centre of Australia, and in S. lat. 45°, beheld an aurora-borealis in the N.E., between 9 and 11 P.M.[1]

355. The *Aurora australis,—südlichter* of the Germans,—differs in no striking particular from the northern-lights. It has been described by Mr Forster, who accompanied Captain Cook ;[2] by M. Simonoff,[3] astronomer to Bellinghausen's expedition, and recently by Sir James Clark Ross.[4] On the 17th February 1773, the meteor was seen in S. lat. 58°, previous to which time, Ulloa had mentioned its appearance to Mairan : in 1745 it was observed off Cape Horn. Dalton, oftener than once, witnessed the southern aurora in this country.[5]

356. When the aurora borealis assumes the form of a wreath near the zenith, it is termed a *corona borealis.* It is only when the polar lights are unusually splendid that this appears, and consequently it may be accounted comparatively rare. When visible, it is seen to flicker round the spot to which the dipping-needle points with its southern pole ; in this country, at the present epoch, that place in the heavens is about 20° from the zenith, with an azimuth of nearly 23° to the east of the meridian. As the magnetic needle declines from the meridian—although its change is slow—this point in space is variable ; it may easily be found, however, in any latitude by finding the amount of *magnetic dip* or inclina-

[1] Leçons de Mét. ; see also Compt. Rend. tom. ii. p. 392 ; Ib. iii. 518, 536, 585 ; Ib. iv. 589 ; Ib. ix. 354, 374, 603 ; Ib. xii. 347.

[2] Cook,—Sec. Voy.

[3] Ed. Jour. of Sc. vol. i. p. 347.

[4] Voy. of Disc. vol. i.

[5] Phil. Tr. No. 461 ; Ib. No. 53, vol. liv.

tion, and *magnetic declination* or variation.[1] This corona is but the convergence of the auroral beams, and the result of perspective. One almost smiles at the hypothesis of Halley,[2] when he explained the coloured corona of the famous meteor of March 6. 1716, illuminated, as he hints, by the direct solar rays, the phenomenon having emerged from the shadow of the earth! While mentioning this, we would refer to a statement made by Sir David Brewster to the British Association in 1837, that he had proved the light of the aurora to be *direct light,* and not that which had been either reflected or refracted. It will be important to keep this in remembrance when endeavouring to explain the phenomenon.

357. The polar lights generally follow a fixed order in their appearance and progress, the more easily observed as we approach the pole. The earliest indication of the phenomenon is a darkening of the sky in the horizon, nearly in the place of the magnetic meridian; this is the first appearance of what has been termed the *dark segment;* the colour of this portion of the sky is a deep grey or violet, passing into black; it does not conceal the stars, which shine as gems through a smoky vapour. The culminating point of this dusky segment is with few exceptions in the magnetic meridian.[1]

Above this haze, and bounding it, there now rises a *luminous arc,* clearly defined below, but unless very narrow, indistinctly limited above, mingling its radiance imperceptibly with the brightness of the sky. This arc is first white, then yellow, with occasionally a greenish tinge. It rests its extremities upon the horizon, though could we see the whole, it would in all probability be found to be a perfect circle whose centre is the magnetic pole; its vertex corresponds with the culminating point of the dusky segment. This arc is in con-

[1] The *magnetic meridian,* in contradistinction to the *polar meridian,* is the great circle of the sphere passing through the point to which the pole of the needle points, or in which it remains suspended *in equilibrio.* In 1657, this meridian at London coincided with the polar meridian; since then, it has been slowly moving to the west, and in 1815, reached a maximum variation (*declination*) of 24° 27′ 18″; in 1831, it was 24°. At Paris, the epoch of coincidence with the pole of the earth's rotation was 1669; in 1814, it was 22° 54′, and in 1829, it equalled 22° 12.5′ west.

[2] Phil. Tr. No. 347; Motte's Abr. v. ii. p. 126.

stant motion, but apart from its flickerings, it increases its chord and advances towards the zenith, bisected all the while by the magnetic meridian. Occasionally one or more arcs appear, in which case they are concentric. Such an occurrence was seen by Sir George Mackenzie[1] in Scotland, on February 13 1822. The luminous arc may be visible for hours before another feature of the phenomenon presents itself.

Luminous beams, or rays, now shoot from the arc, singly or in numbers, with great velocity towards the zenith, or rather to that portion of the sky which is soon to display the auroral crown. These beams preserve a parallelism to the magnetic meridian, though from being seen perspectively, they appear to converge towards the opposite poles of the dipping needle. They are in continual vibration and changing form—at one time they rise but a few degrees above the arc,—at another, they transform the sky into a cupola, magnificent in the brightness of its radiating columns as it is grand in the magnitude of its proportions. No less beautiful are these rays in the splendour of their colouring and intensity of shade. Sometimes they are mingled with columns of smoky darkness; and this leads us to the observation that black beams occasionally appear below or within the arc, mobile as those on the other side, and apparently connected with the segment in the horizon. Finally, and as if the climax, these "burning spears" gather in the upper heavens, forming a radiant wreath or *crown*, and then they disappear. The phenomenon is at an end,—the aurora is broken up—perchance some curdled masses remain, but they too vanish. Although the arc which we have described moves generally from the N.W. to S.E., it does not always do so: on the 21st of January 1826, Professor Forbes of Edinburgh[2] observed one which followed a course from N.E., to S.W., crossing the zenith, and moving diametrically against the wind,—notwithstanding a bright moonlight, the two small stars of the 6th and 7th magnitude which form ν *Cassiopeiæ* were visible to the naked eye *through* this auroral arc. Rarely does the auroral arc retrograde to

[1] Ed. Phil. Jour. vol. vi. p. 380.

[2] Rep. Brit. Assoc. vol. i. p. 256; Ed. Jour. of Sc. ix. p. 130.

the place where the first impression of the meteor was obtained.

358. The aurora borealis is of various hues and shades of colour.[1] The *segment* on the horizon, as has been already observed, though inclined to black, has been seen by Bergman and Hansteen, of a grey and violet colour. The *arcs* are sometimes violet-blue, golden-yellow, ash-grey, crimson-red, white tinged with yellow on the edge, but generally white. The *rays* have been seen to present the following tints,—yellowish-grey, steel-grey,[a] golden-yellow, apple-green, celandine-green,[b] violet-blue, rose-red, crimson, columbine-red,[c] hyacinth-red,[d] cherry-red, greenish-red, greyish-black, and smokey-black. The *lustre* of this meteor differs in kind and degree,—steel-grey, pearly, and sometimes, imperfectly vitreous.

359. Very dissimilar estimates have been made of the altitude of the polar lights, arising doubtless in early instances from limited data, and in some recent observations from optical illusions. The meteor is doubtless above the limit usually assigned to our atmosphere, but its height does not exceed a 180 miles. Kraft computed the altitude of one seen on the 16th of March 1730, at Petersburgh, at 133 miles, and that of another, witnessed on the 6th of September, at 160 miles. Mairan, at Paris, and Horrebow, at Copenhagen, estimated that of February 22. 1735, at 454 miles. That of the 16th December 1737, Father Boscovich computed to be elevated 825 miles, but De Fouchy at Paris, and Plantade at Montpellier, estimated the height of the same aurora borealis at 553 miles. Bergman[2] of Sweden calculated one seen on the 8th November 1760, at 334 miles, and another, observed on the 22d February 1764, at 254 miles. Cavendish, from the meteor of February 23. 1784, computed the height at from 52 to 71 miles only. Dalton[3] in a paper read before the Royal Society on the 17th April 1828, estimates the altitude of the

[1] Professor Jameson,—Enyc. Brit. 7th ed. vol. iv. Art. *Aur. Bor.*; Mineralogy,—*Colour*:—[a] Steel-grey,—ash-grey with metallic lustre; [b] Celandine-green,—Emerald-green mixed with sapphire-blue and ash-grey; [c] Columbine-red,—Carmine with much berlin-blue and a little black; [d] Hyacinth-red,—Carmine with lemon-yellow and a little brown.

[2] Opusc. v. 291, where a table of numerous observations will be found.

[3] Met. Essays; Ph. Tr. 1828, p. 291.

meteor of the 29th March 1826, seen over a wide extent, at 100 miles. On a previous occasion (1793) while at Kendal, he made observations in connection with Mr Crosthwaite at Keswick,—about 22 miles distant, and upon the same magnetic meridian,—from which he computed the height of an auroral arc seen by both, at 150 miles. The Rev. Mr Farquharson of Alford, Aberdeenshire, objects to these conclusions, and supposes the meteor of 1826 to have been only a few thousand feet above the ground. Professor Potter of London, while at Manchester, observed, in connection with Dr Burney at Gosport,—about 193 miles distant, and on the magnetic meridian,—an aurora on the 29th September 1828, from which he calculated the altitude of the upper edge of the arc to be from 197 to 218 miles.[1] It was visible to the south of the zenith at Manchester, and to the north of it at Gosport. On December 12. 1830, Dr Burney at the same place, and Mr J. Blackwall, near Manchester, calculated the height of an aurora at from 99 to 134 miles; according to a formula of Professor Potter, this aurora was at the altitude of 108 miles. Three years later, an auroral arc, observed at Edinburgh by Professor Forbes, at Armagh by Dr Robinson, and at Athboy by Lord Darnley, was computed by Professor Potter, from data furnished by these gentlemen, to have been at an altitude of nearly 143 miles. Professor Airy, from data derived from the fine auroras of the 17th September and 12th October 1833, the former of which, he says, were "connected with the clouds visible at Cambridge,"—evidently not the aqueous meteors near the earth, which float comparatively low—estimated the height of the former at 60, and that of the latter at 50 miles: the observations were made at Armagh, Gainsborough, York, Dent, Manchester and Cambridge. Professor Potter computed the altitude of the same meteors at from 56 to 85 miles. From data collected on auroral arcs seen March 22. 1841, March 19. and September 21. 1847, Professor Chevallier[2] has computed the altitude of this meteor at from 106 to 175 miles. The first of these arcs was observed at Dunse, by Mr W. Stevenson; at Durham, by himself; at

[1] Athen. No. 938; see Capt. Kater,—Ph. Mag. N.S. iv. 337; Gilbert,—Ib. 453; Harvey,—Ed. Jour of Sc. x. 146.

[2] Brit. Assoc. 1847; Athen. No. 1029.

Belfast, by Professor Stevelly; and at York, by Mr Phillips; giving a result of from 156 to 165 miles: the second was seen at Darlington, Spalding in Lincolnshire, Cambridge, Norwich, Oxford, London, and Amsterdam; giving a mean height of 175 miles,—a great *magnetic storm* took place at Toronto: and the third was witnessed at Esk, near Durham, by Chevallier, and at Norwich by Mr Marshall; giving a result of 106 miles. These trigonometrical measurements, give the nearest approximation to the real altitude of the aurora borealis yet obtained. The observation by Parry of a ray darting between him and a distant hill, was fallacious, for it was nothing more than the continuance of the impression upon the retina after the meteor had vanished. Attention has been directed to an apparent connection between the polar-lights, and the lofty cirro-stratus, and cirro-cumuli clouds,—which probably are *magnetic* precipitations during the *magnetic storms* of the auroræ,—but here we must guard against error, and be not led to measure the altitude of the clouds instead of that of the luminous meteor.

360. The aurora borealis is subject to periodical visitations, for some years it will illuminate the firmament at brief intervals, and again, as if reposing from its toils, cease for a considerable number to appear. Already have we noticed the paucity of observations in the 17th century; early in the 18th, they burst out and continued increasing in frequency and brilliancy till about the middle of that century, when there was a temporary retrogression. Within the last few years, some of the appearances have been extremely grand and frequent. Besides these *secular* periodicities, the aurora borealis is subject to *mensual* maxima and minima. Applying the principles of statistics to a large number of recorded phenomena, we find that the mean number of appearances of the aurora borealis during the year, are as follows:—

January . . .	7.0$\frac{3}{8}$	July	2.7$\frac{0}{8}$
February . . .	9.4	August . . .	6.7
March . . .	13.3	September . .	12.4
April . . .	9.6	October . . .	15.3
May . . .	5.7	November . .	8.8
June . . .	2.0	December . .	6.9

This table gives for the *seasons* the following results :—

Spring, ...	March, April, May, ...	28.88
Summer, ...	June, July, August, ...	11.4
Autumn,....	September, October, November, ...	36.5
Winter,.....	December, January, February, ...	23.3

from which the following proportions are derived,—spring, *to all the other seasons*, as 1 to 2.5 ; summer, as 1 to 7.8 ; autumn, as 1 to 1.7 ; and winter, as 1 to 3.3. In describing the aurora in its individual phases, it will be observed that a striking order in the succession of the phenomena is presented. This would lead one to expect, that, in addition to the other periodical appearances, there should be likewise a *diurnal periodicity.* It is so. In our latitudes, the presence of the sun may be thought to conceal these meteors—we doubt not in many instances it does so,—but in the mass of observations, it is after sunset that the auroral arc rises in the north. In the polar circle, where there is but one day and a solitary night throughout the year, and where the opportunities of studying the phenomena are upon the grandest scale, the same striking feature of horary regularity is preserved. Bravais remarks that the rays are exhibited most generally about 10 P.M., and rarely after 4 A.M. ; while the nebulous masses or plates which terminate the spectacle, appear towards morning.

361. The influence of the polar lights upon the magnetic needle was noticed by Halley, in this country ; by Celsius and Hiorter, on March 1. 1741, in Sweden ; and by Cassini and Cotte, in France. Since then, it has been observed by Wargentin, Van Swinden, Bergman, Biot, Gay-Lussac, Hansteen, Robison, Dalton, Kupffer, Arago, Reiss, Franklin, Richardson, Back, Farquharson, and others. Van Swinden observes, that he rarely found that the aurora did not immediately follow any anomalous motions of the needle. We have already mentioned that the culminating point of the arc, the direction of the rays, and the position of the auroral crown, are all in, or run parallel to, the magnetic meridian[1]—the arc itself is but a multitude of rays pointing to the magnetic pole, and so

[1] See Note [1] p. 357.

arranged, that perspectively they assume the form of a bow. These facts alone, shew a peculiar connection in this meteor with terrestrial magnetism. The nature of the motion communicated to the needle, Sir John Franklin[1] describes—from observations at Fort Enterprize,—as being neither sudden nor vibratory. Sometimes it was simultaneous with the first appearance of the aurora, or with certain changes in its aspect, but generally it was not immediately visible; in about an hour, however, after the vibrations were perceived, it had reached its maximum deviation, but was slow in regaining its original position. He observed that the disturbance of the needle was not invariably proportioned to the agitation of the meteor, but was always greater when the quick motion and vivid light appeared in a hazy atmosphere. Professor Faraday and Mr Christie did not fail to observe a striking magnetic effect from the aurora of the 19th April 1831.[2] Dr Dalton[3] made some valuable observations upon the subject, between the years 1786 and 1793. From one series, he found the deviation of the needle amounted to 53′. At Fort Reliance, in N. lat. 62° 46′ 29″, and W. long. 109° 0′ 39″, Captain Back found it once so much as 8°. Farquharson[4] observed that the variation reached its maximum when the auroral beams had passed the zenith to the south ; and this was confirmed by Richardson in the arctic regions. Hansteen observed that the magnetic *inclination* or dip, was increased shortly before the breaking out of the aurora, but that it returned *to par* soon after the appearance of the meteor ; Bravais confirms this from observations at the Bay of Alten in N. lat. 69° 58′. Hansteen noticed likewise, that when the vertex or place of the corona borealis changed, the needle moved, and seemed to follow it. Thus we find that the needle vibrates during the play of this meteor not only in *declination—magnetische abweichung,*—but in *inclination—magnetische neigung,*—though the former variation is the one most commonly recognised. These oscil-

[1] Nar. of Jour. to Shores of Polar Sea, 1819–1822, appendix, 4to.
[2] Jour. of Roy. Inst. Dec. 1831, p. 271. [3] Met. Obs. and Essays.
[4] Phil. Tr. 1830 p. 97 ; Ed. New Phil. Jour. v. vi. p. 392.

lations of the needle under the influence of the polar lights, have been called by Humboldt *magnetic storms.*

362. From a long-continued series of observations upon *magnetic storms,* at Paris, M. Arago found that the needle was affected in that city by auroræ visible in Scotland, and he infers the existence of the one from the indication of the other. This philosopher has also shewn, that this meteor, though visible only in North America, St Petersburgh, and Siberia, produced magnetic disturbances in his observatory. He even considers that the *southern aurora* influences the compass in our northern latitudes. M. Kupffer, with an apparatus similar to that used by Arago, remarked that the motions of the needle at Kasan, took place at the same instant with those at Paris. During a display of the polar lights, the intensity of the earth's magnetism is diminished, in consequence of which the needle recedes from the pole where the auroral beam is displayed: before the meteor is visible, or just upon its appearance, the disturbing forces act in opposite directions, attracting towards the northern pole. We are not aware that the curious and anomalous result of Foster's experiments at Port Bowen, near the magnetic pole, has been satisfactorily explained: this officer found *no* oscillations of the needle there during the polar lights, although from other causes, the diurnal variation of the compass was sometimes equal to five degrees.

363. An odour has been remarked to attend the aurora. Mr W. C. Trevelyan learned in Faroe, that during a very luminous appearance of the northern lights, the peculiar smell which accompanies electrical discharges was distinctly felt. The odour is probably owing to the presence of a new principle, recently recognised by Schönbein, and designated *ozone.*[1] This peculiar substance is supposed to be a superoxide of hydrogen, and possesses a strong analogy to chlorine. It possesses a very energetic oxydising power, and may be destroyed by olefiant gas, ether, sulphureous, hydrosulphuric, and hyponitrous acids; it decomposes all salts of manganese; air in contact with a solution of hyponitric acid acquires pro-

[1] Ozone, (ὄζω, oleo). Rep. Proceed. Brit. Assoc., &c.

perties analogous to those of ozone, producing with iodine, effects similar to those developed by that element. This chemist regards it as constantly present in our atmosphere, liberated there in variable proportions dependent upon the development of electricity. To prove its existence, and test approximately its quantity, he suspends sheets of paper prepared for the purpose by immersion in a solution of starch and iodide of potassium; if present, and the atmosphere humid, the paper will become blue, but if the atmosphere is dry, the tint will be brown.[1] Dr Moffatt communicated to the British Association,[2] some observations upon the influence of this curious principle, and he has observed what Schönbein[3] also has noticed, that an increase of ozone is invariably attended by catarrhal affections. Professor Schönbein ascribes the luminosity of phosphorus to ozone.

364. If we are to believe the statements of certain modern observers, that the aurora borealis has been heard to emit sounds, we may credit and explain some references to aërial noises which occur in classical authors.[4] Virgil, describing the prodigies at Cæsar's death, says,—

> "Armorum sonitum toto Germania cœlo
> Audiit."
>
> *Georg.* lib. i. v. 473.

Tibullus refers to the same, and it is mentioned by Suetonius. Sir John Franklin[5] confirms the statement of Sir John Richardson, that though he had never heard the sound emitted by the polar lights, yet the natives, Crees, Copper Indians, and Esquimaux, with the older residents in that country, testified that sound was emitted during the play of the aurora. Lieutenant Hood, who accompanied Franklin to the Arctic Regions, observes, "we repeatedly heard a hissing noise, like that of a musket-bullet passing through the air, which seemed to proceed from the aurora, but Dr Wentzel assured us that

[1] Zeitschrift für Rationelle Medizen. [2] Meeting at Swansea, 1848.

[3] Journal de Chimie Médical, July 1848.

[4] Virgil *in loc. cit.*; Tibullus.—lib. ii. v.; Ovid,—Met. 15; Pliny,—lib. ii. cap. 57; Suetonius, &c.

[5] Franklin and Richardson,—Jour. to Shores of Pol. Seas.

the noise was occasioned by severe cold succeeding mild weather, and acting upon the surface of the snow previously melted in the sun's rays. The temperature was then —35° F., and on the two preceding days it had been above zero." Musschenbröck,[1] Gmelin,[2] Sir Charles Giesecké, and Cavallo,[3] make mention of it as an undoubted fact, and Hansteen[4] observes, "we have so many certain accounts of the noise attending the polar lights, that the negative experience of southern nations cannot be brought in opposition to our positive knowledge." Professor Parrot of Dorpat, on the 22d October 1804; Mr Nairne; M. Ramm of Törset, in Norway; Wargentin;[5] Abrahamson;[6] Brooke;[7] Belknap;[8] Dr Henderson,[9] in Iceland; Professor Jameson,[10] in Shetland, and on the mainland of Scotland; and Hearne, at the mouth of the Coppermine River, give *positive* testimony to auroral sounds. Against this evidence, however, we have the *negative* opinion of the members of the French Commission,—MM. Lottin, Bravais, Lilliehook, and Siljestroem,—at Bosekop; Thienemann, in Iceland; Wrangel and Anjou, on the Siberian coast of the Polar Sea. The velocity of sound does not appear to have entered as an element in the determination of this question. Baron Humboldt[11] quaintly observes, that "the auroras have become more silent since observers have better understood how to observe them, and how to listen for them."

365. On entering upon the question of the origin of this meteor, the following circumstances must be kept in remembrance:—its electro-magnetic influence, its great height, and the fact that its light is *direct*. Many theories have been proposed to account for the aurora borealis, some of which we shall mention. Mairan[12] conjectured that it is an offshoot from

[1] Instit. Phys.
[2] Blagden,—Phil. Tr. vol. lxxiv.
[3] Elem. Nat. and Exper. Phil., iii. 449.
[4] Mag. für Naturwidenskaberne, Christiana, 1825.
[5] Trans. Swed. Acad. vol. xv.
[6] Trans. Scand. Lit. Soc.; Edin. Jour. of Sc. vol. v.
[7] Trav. in Norway.
[8] Amer. Tr. vol. ii. p. 196.
[9] Resid. in Iceland.
[10] Encyc. Brit. 7th ed. *art.* Aur. Bor.
[11] Cosmos, v. i. p. 185,—Sabine, 1847.
[12] Traité Phys. et Hist. de l'Aur. Bor.; Mem. Fr. Acad. 1733, containing observ. on Zod. light, towards support of this theory; and 1747, where he defends against Euler.

the solar atmosphere. Euler's theory of the impulse of light disturbing the upper atmosphere, is equally untenable.[1] St Pierre assigns the phenomenon to coruscations of ice, an appearance sometimes witnessed before icefields come into view. In 1835, Sir John Ross offered another explanation of the phenomenon,—"that it was caused by the sun's rays striking on the circumpolar fields of ice and glaciers, and then reflected from very thin clouds aloft in the atmosphere."[2] Sir John Ross was led to propose this theory from what must have been mistaken observations upon the altitude of the aurora, arising most probably from the impression of the meteor upon the retina. Against it, we have the positive experiments of Brewster,[3] proving that the auroral beams are not reflected light; and their altitude is far above the region of clouds. This theory of Ross has a prototype in that of Monge, who supposed the phenomenon to be clouds illuminated by reflexions of solar light from other clouds.[4] Libes[5] ingeniously explains the meteor by an electrical decomposition of the gases of the atmosphere, a conjectural hypothesis, against which the altitude of the aurora may be urged. The argument of the height of the polar lights has suggested to Professor Potter of London another theory. "Its cause," he says,[6] "must be sought in extraneous matter arriving within the influence of the earth's magnetism, or electro-magnetism. I have therefore given an opinion, which I still believe to be the correct view, that the phenomena of the aurora borealis are caused by gaseous matter, much more rare than Encke's or Biela's comets, which in its path in space comes within the earth's influence." Referring to a magnificent burst of the aurora in November 1837, when the earth had passed into "the mysterious meteor region," Professor Nichol[7] has hinted a singular conjecture. Speaking of the near escape which we had of being in-

[1] Mem. Acad. Berlin, 1746, p. 117.
[2] Brit. Assoc.; Athen. No. 407, p. 618, Aug. 15. 1835.
[3] Edin. Encyc.—Art. Electr. vol. viii. p. 492.
[4] Leçons de Physique, par Pujoulz. 1805, p. 237.
[5] Traité de Physique; Libes,—Diction. de Phys.; Rozier's Jour.; Lond. Encyc.
[6] Athen. No. 938, p. 1018. Oct. 18. 1845.
[7] Thoughts relating to Syst. of World.

volved in the monstrous tail of a recent comet, which preceded the earth in its orbit by only fourteen days, he observes, —"But if that mist, thin though it was, had, with its next to inconceivable swiftness, brushed across our globe, certainly strange tumults must have occurred in the atmosphere; and probably no agreeable modification of the breathing medium of organic beings. Right certainly, to be most curious about comets; but prudent withal to inquire concerning them from a greater distance than that: although one night in November 1837, I cannot be persuaded that the earth did not venture on a similar, but comparatively small experiment."

366. The magnetic relations described, indicate a close affinity between the aurora borealis and magnetism, which is merely a particular form of electricity; consequently the polar lights may be classed with the electric meteors of our atmosphere. Such was conjectured by Halley[1], and is held by Dr Thomas Young,[2] Dr Dalton,[3] Sir David Brewster, and others. This theory explains the parallelism of the rays with the magnetic needle, and the intensity of the phenomenon near the magnetic poles and its decrease as we recede towards the *magnetic equator*. The correctness of this view is supported by the appearances presented on passing electricity through air rarefied a thousand times, which are identical with those of the auroral beams. The analogy is preserved by the experiments of De la Rive,[4] who, availing himself of the powerful battery of Grove, consisting of forty pairs of plates, and attaching charcoal to the ends of the conducting wires, obtained, on approaching their points, an arch of exquisite splendour, an inch in length;[5] but this was not all, this arch of electric light was found to be obedient to magnetic influence vacillating between repulsion and attraction as one or other of the poles was presented. The aurora borealis, says Sir John Herschel, "is certainly connected with the general cause of magnetism," and again, in reference to the agency of electricity, "this wonderful agent which we see in intense activity in lightning, and in a feeble and more diffused form tra-

[1] Phil. Tr. No. 341, v. xxix.
[2] Lec. Nat. Phil. vol. i. p. 687.
[3] Met. Obs. and Essays.
[4] Proceed. Elect. Soc. pt. ii. p. 75.
[5] The "Electric Light" of the present day!

versing the upper regions of the atmosphere in the northern lights, is present probably in immense abundance in every form of matter which surrounds us, but becomes sensible only when disturbed by excitements of peculiar kinds."[1] The *dark segment* below the auroral arc is, according to Argelander, something real, and not as Struve supposes, merely a contrast with the luminosity above: he founds this opinion upon the fact—that the dusky segment appears *before the arc is visible.* When more luminous arcs are seen than one, they are believed to arise by reflexion from frozen crystals floating in the atmosphere.

367. The zodiacal light is first mentioned by Childrey[2] in 1659, and again by Kepler, who describes it with considerable accuracy and theorises upon its cause. It received this name from Dominic Cassini,[3] who witnessed the phenomenon on the 18th March 1683. Derham[4] describes it as seen on 3d April 1707 about a quarter of an hour after sunset. The zodiacal light is a luminous appearance of a flat lenticular form, inclined obliquely to the horizon, and stretching to a considerable distance from the sun. It may be seen on very clear evenings, though in this climate imperfectly, soon after sunset, from the months of March to May; and again, before sunrise at the opposite season. Its direction is in the plane of the sun's equator, and the apparent angular distance of its vertex from the luminary varies from 40° to 90°; the breadth of its base, at right angles to its axis, is from 10° to 30°. Although these are the general dimensions of this luminosity, Pingré observed one in the torrid zone, which extended from the sun 120°, and had a horizontal breadth of from 8° to 130°.[5] Humboldt,[6] in the valleys of Tuy and Aragua in South America, turned his gigantic mind to the study of this phenomenon. There he observed it as a faint luminous pyramid, rising from 53° to 60° above the horizon. Without any assign-

[1] Prelim. Disc. Nat. Phil. 1833, *art.* 368, p. 329.
[2] Childrey,—Britan. Bacon. 1661, p. 183.
[3] Mém. de l'Acad. 1730, tom. viii. p. 188.
[4] Ph. Tr. No. 310, p. 2411.
[5] Encyc. Edin. *art.* Astron. vol. ii. p. 619.
[6] Person. Narrative.

able cause from atmospheric influence, its intensity would vary within a few minutes. At times it was brighter than the galaxy in *Sagittarius*, and possessed an undulatory motion. The probable connexion between the zodiacal light and electricity, leads us to mention, that at the plantation of Tuy, the oscillations of the needle were 22.8 per minute.

368. Fatio Duillier, and others, have remarked the resemblance of the zodiacal light to the tails of comets ; and some have explained it by this cause. Kepler, Cassini, Mairan, and others, have ascribed it to a solar atmosphere extending beyond the luminous and calorific zone which encircles that orb. Laplace[1] has shewn that this hypothesis is untenable, upon the balance of the two great powers, gravitation and centrifugal force. Dr Wollaston[2] has disproved the idea of such an extension of the solar atmosphere as would be required for the production of the zodiacal light upon this hypothesis, by the phenomena attending the passage of Venus close to the sun, in May 1821, an observation similar to that of Vidal[3] of Montpellier, on the 30th May 1805. Upon both of these occasions, the apparent and computed position of the planet was the same, though in the one it approached within 51′ 15″ (Wollaston), and in the other, within 46′ (Vidal), of the centre of the sun's disc. Another, and more plausible theory, is that which gives it a place with terrestrial phenomena, and supposes it to be a luminous meteor occupying the loftiest regions of our atmosphere. Baron Von Humboldt[4] ascribes it, as Cassini once imagined, to an uncondensed ring of *world-vapour—welt-dunst*—between the orbits of Mars and Venus ; but against this theory we would observe that the existence of this matter has not yet been proved, and the nebular hypothesis—to which the Baron adheres—has been doomed to a subordinate place in the annals of Astronomy. Sir David Brewster,[5] offering a conjecture relative to its nature, asks if we may not " *conceive* even that the earth may leave traces of its path in clearing its annual way through the etherial void ?"

[1] Syst. du Mondo.
[2] Phil. Trans. 1822, part i.
[3] Conn. des Temps. 1808.
[4] Cosmos, vol. i.
[5] North Brit. Rev. vol. iv. p. 227, 1845.

369. The last of the luminous meteors which we shall describe is the *Ignis Fatuus*, Will-o'-the-bush, Jack-with-a-lanthern, or *Scoticè* Spunkie. It is seen at night, generally in marshy places :

——"Sometimes from rushy bush
To bush it leaps, or, cross a little rill,
Dances from side to side in winding race
——leading from the path
To faithless bogs, and solid seeming ways."
GRAHAM,—*British Georgics.*

It appears upon dunghills and in grave-yards, flickering about with unsteady light, and receding from the observer on his approach. It has been remarked that this meteor occurs more frequently in the autumnal season than in the other months, probably because the circumstances which lead to its production are then developed most abundantly ; and supposing it to be a gas of terrestrial origin, the pressure of the air at that period of the year by its frequent changes, may be favourable to the escape of the elastic fluid. The ignis fatuus is generally of a pale bluish colour, and seems brightest at a distance. Newton defined it as "a vapour shining without heat."

370. The Ignis fatuus was finely seen near Birmingham[1] on December 12. 1776. Dr Derham once observed it play around a thistle, but it flitted away by the movement of the air when he got within a few feet of it. A curious appearance of the meteor was witnessed by Dr Shaw[2] in one of the valleys of Ephraim, where it seemed to run along the ground for upwards of an hour, and expanded itself over two or three acres of the adjacent mountains. It appeared about 1480–81 upon the continent more frequently than ever previously in the recollection of the inhabitants—at that time the plague was raging in Europe.[3] Beccaria[4] describes it as seen at Bologna, where, about 150 years ago, it was very common. It was nightly visible to the N. and E. of that city, and peculiarly brilliant to the east, in the fields of Bagnara He esti-

[1] Priestley,—Exper. and Obs. on Air, append. vol. iii.
[2] Trav. in Holy Land, &c.
[3] Epidem. Mid. Ages,—Hecker.
[4] Phil. Trans.

mated the luminosity as equal to the light of an ordinary faggot—one which accompanied a friend for a mile along the road, shone like a large torch. Its appearance was not constant; it came and went—rose and fell—would hover six feet from the ground—would contract its volume and expand—would separate and again unite—assuming the form of a luminous wave and dropping brilliant scintillations. M. Doe[1] mentions a fine appearance of this meteor on the evening of May 26. 1821, in the marsh of the Chapelle-aux-Planches, in the Department of the Aube. It resembled a pyramid of pale red light, from ten to twelve feet high, so bright that one could read by it, but it had no heat. After half an hour, the mass of light broke into patches, which dispersed themselves over the marshy ground. Dr Quirino Barillic Filepauti[2] mentions, that one evening Onofrio Zanotti observed this meteor issuing from the ground between the paving stones of the street of Lungo-Reno, in Bologna, near the house of Professor Santini; it is stated too, and this is remarkable, that he felt the *impression of heat.* On one occasion he observed the meteor near the town, moving horizontally, and carried by the breeze to the banks of the Idice in Bolognese, where it disappeared. Another time, in October, as he was watching the ignis fatuus in the parish of San Donino, about two miles from the city, upon a field in which there is a pool, the meteor appeared about 11 P.M. At the distance of twenty feet it presented the usual appearances, with a slight emission of smoke; it was moving slowly from S. to N., but changed its direction on being approached, ascended, and vanished—not, however, till a long rod previously prepared with some flax tied to the end, was thrust into the flame *and kindled.* That heat should have been experienced and flax ignited is so remarkable as to cast some doubts upon the correctness of the observation: we should like to know of a similar result before dismissing the generally received opinion that this meteor is *merely luminous.*

371. Reflecting upon this subject, many instances start to mind, which shew that though light and heat are intimately

[1] Jour. de Phys. tom. xciii p. 236, Sept. 1821.

[2] Annali di Fisica.

connected, the former may exist without the other being appreciable. There are many illustrations of their separate existence, *i.e.* of the absence of the sensible properties of caloric in light-giving bodies,—we would distinguish between the luminosity of living bodies, and that which appears on organic matter deprived of vitality. This property is possessed by several of the *Annelides, e.g.* the *Nereis noctiluca* (Lin.), and others more recently detected.[1] It is met with in many of the *Mollusca,* particularly those belonging to the *Acephala tunicata,* as the *Pyrosoma* of various species, and *Salpa;* in the bivalve molluscs, the *Pholas;* likewise in some belonging to the great divisions *Cephalopoda* and *Pteropoda.* We find the same quality possessed by several of the *Crustacea, e.g.* the *Cancer pulex* (Lin.), *c. fulgens* (Banks). Certain fish are supposed to be luminous, as, for example, a *scopelus,* but it is uncertain if the property is not due to phosphorescent animalculæ attaching themselves to their scales. It is an attribute belonging to many of the *Zoophytes,*[2] particularly to most of the *medusæ;* among the *acalephes* properly so called, to the *noctiluca,*[3] and *beroë*—the cilia of the *Cestum veneris* are vividly luminous, and exquisitely beautiful as it glides along like "an undulating flame several feet in length;"[4]—among the *polypes,* to the *Sertularia pumila,* and other species; to the *pennatula;* to the *flustra,* the *membranipora,* and others.

> "Awaked before the rushing prow,
> The mimic fires of ocean glow,
> Those lightnings of the wave;
> Wild sparkles crest the broken tides,
> And, flashing round the vessel's sides,
> With elfish lustre lave;
> While, far behind, their livid light
> To the dark billows of the night
> A gloomy splendour gave."
>
> SIR WALTER SCOTT,—*Lord of the Isles.*

[1] Phosphorentia maris quatuordec. lucescent. animalc. novis spec. illust. Genevæ, 1805.

[2] See Dr Johnston,—Hist. Brit. Zoophytes; Thompson,—Zoolog. Research.; Cuvier,—Anim. King.—Griffiths; Tiedemann,—Comp. Physiol. i. 259; Ed. New Phil. Jour. vol. v.; Mag. Nat. Hist. vols. iii. iv. v. vii. ix.; Proceed. Zool. Soc. Jan. 1837; Dr Fleming,—Hist. Brit. Animals; Dr Macculloch,—Hist. Western Islands of Scotland.

[3] Mag. of Zool. and Bot. vol. i. p. 492.

[4] Rymer Jones,—Outline of Anim. Kingd. p. 77.

Two species of *Myriopoda* or *centipedes* are luminous,—the *Geophilus phosphoreus* of Asia, and the *G. electricus* of England.[1] This property is met with in many of

> "The winged lights
> That spangle India's fields on showery[2] nights."

The beetles or *coleopterous insects* furnish the largest number of these light-giving creatures. The fire-flies of Guadaloupe and other places, especially the *Fulgora lanternaria* (Lin.), a hemipterous insect three inches long, and native of South America, the *F. candelaria* of China, the *F. diadema* and *pyrrhorhynchus* of India. Above twenty species of the *Elateridæ* are luminous; the best known are the *Elater ignitus*, and *noctillucus* or *cocuyos* of the West Indies. Humboldt,[3] describing the effects produced by them, says, "it seemed as if the starry firmament reposed upon the Savannah!" He mentions that they are used as lamps when confined within a calabash pierced with holes, and instances the case of a young woman of Trinadad, who, when at sea, suckled her child by the light of these insects. Another family, the *Lampyrides*, contains nearly two hundred species having the same property; of them the *Lampyris noctiluca* (Lin.), or glowworm, is a familiar example; the *Pygolampsis italica* affords another illustration. The same curious property is possessed by the Vegetable Kingdom; thus some of the *fungi* are phosphorescent,—the *rhizo-morpha* of mines, vaults, and cellars, the *Agaricus olearius* of De Candolle, also a large species found in Australia, and described by Drummond. Gardner[4] mentions having unexpectedly met with another luminous fungus in Brazil, called by the natives *Flor do Coco*, growing upon the decaying leaves of a palm, and giving out a bright pale greenish light, similar to that emitted by a cluster of *pyrosomæ*. He found children at play with this fungus in the streets of the Villa de Natividade. The same quality has re-

[1] Leach,—Linn. Tr. xi. 384; *Scolopendra elect.*—Geoffroy, Hist. des Insects, ii. 676, 5.

[2] Carreri,—Trav.; Moore,—Lallah Rookh.

[3] Person. Nar.

[4] Trav. in Brazil, p. 346.

cently been discovered in a tree found in the jungles of Burmah, and lately shewn to the Asiatic Society. The *nasturtium* and some other garden flowers are said to be phosphorescent. Even certain secretions of the body are found occasionally to be luminous.[1] Is this phosphorescence a quality or attribute of certain matters, or does it depend upon new combinations of their chemical constituents?—does it arise from light developed by unknown cause, from molecular structures in which it has been hid?—or are both in operation? This is an inquiry eminently suggestive. The phosphorescence of certain fish, seems to arise after death and before decomposition has fully set in, from the evolution of phosphuretted hydrogen; but this gas becomes extinguished as putrefaction advances, probably by the disengagement of ammonia, and its union with the other gas. Phosphuret of nitrogen is luminous likewise when in contact with the atmosphere. On the electrical theory of phosphorescence, we refer to the work of Becquerel.[2]

372. Returning from this digression to the ignis fatuus, which, true to its character, has flitted from us when we wished to make its most intimate acquaintance,—we would observe, that its particular cause is unknown. Some assign to it an electrical origin; others believe it to arise from chemical products of decomposition, in which case it is most probably phosphuretted hydrogen, a gas spontaneously inflammable in the presence of atmospheric air. The suggestion of this gas as an explanation of the meteor, recals the chimera of sepulchral lamps perpetually burning. The sober matter-of-fact man may join the sceptic in rejecting the fable, though told by Licetus,[3] of the unextinguishable lamp in the tomb of Pallas, the hero of the Mantuan bard,[4] discovered about the year 800, after being shut up nearly 2000. Are we to accept the account of the burning lamp of Olybius, encased in its double urn; or that of Tulliola, which was said to be found

[1] Jurine,—Bib. Med. Nov. 1813; Guyton-Morveau,—Annal. de Chimie, tom. lxxxix. p. 182; Reisel,—Miscel. Acad. Nat. Curios. Dec. 1, An. 6 and 7, p. 280; Willis,—Urin. Dis. 1838, p. 134.

[2] Traité de l'Elect. et du Magnetisme; Annal. de Chimie et de Phys. *passim.*

[3] Fortunio Liceti de Reconditis Antiq. Lucernis; Octavio Ferrari,—De Vet. Lucer. Sepulc.

[4] Æn. vii.

burning, when in the time of Pope Paul III.,—fifteen centuries after Cicero had bewailed the loss of his daughter,—her sepulchre was accidentally opened? But what shall be said of Camden in the seventeenth century, or of the alleged discovery in Spain in the present era? This antiquarian and historian tells us, that the vault in York where the remains of Constantius Chlorus reposed, was violated when the monasteries were ransacked, and the sepulchral lamp was found burning,—but it immediately extinguished! So at Bacna in Spain, near the Castellum Priscum, between Granada and Cordova, so late as August 1833, another ignited sepulchral lamp was discovered. Like the former, the flame instantly expired, and the vessel was broken from its fastenings on attempting its removal.[1]

[1] Commun. of Mr Wetherell of Seville to the Archæolog. Inst., read at York, July 24. 1846.

CHAPTER XV.

"'Tis the voice of the wind! 'tis the rush of the breeze!
Whence came it? Thou know'st not,—and whither retired?
Thou know'st not. It came.—It was felt.—It expired.

373. When by any cause the atmospheric molecules are disturbed, the motion communicated to the air is denominated Wind: it arises as a consequence of changes in the density of the atmosphere. Like water seeking its own level, the particles of air rush to supply the partial void, with a velocity and impetuosity proportioned to the exciting cause; so in the higher regions, those particles which, expanded by heat, have ascended by reason of their diminished gravity, flow out according to a similar law, and thus two currents are established, one on the surface of the earth, and the other considerably above, moving in opposite directions—vide 380. Mr John Smeaton[1] has constructed a table of the velocity and force of winds, calculated in the course of erection of windmills by himself and Mr Rouse of Leicestershire.

[1] Phil. Tr. vol. li. A fuller table will be found in the Edin. Encyc. vol. ii. p. 76; see also Lamouroux,--Geog. Phys. 103.

Velocity of the Wind.		Perpendicular Force in ℔ avoird. per square foot.	Ordinary Name of the Wind.
Miles per Hour.	Feet per Second.		
1	1.47	0.005	Hardly felt.
2	2.93	0.020	Light breeze, barely perceptible.
3	4.40	0.044	
4	5.87	0.079	Gentle breeze.
5	7.33	0.123	
10	14.67	0.492	Brisk pleasant gale.
15	22.00	1.107	
20	29.34	1.968	Very brisk gale,—*fresh.*
25	36.67	3.075	
30	44.01	4.429	High wind, or strong gale.
35	51.34	6.027	
40	58.68	7.873	Very high wind, or hard gale.
45	66.01	9.963	
50	73.35	12.300	Hurricane; tempest.
60	88.02	17.715	
80	117.36	31.488	Violent Hurricane, tearing up trees, overturning buildings, &c.
100	146.70	49.200	

374. Winds are propagated, either in a direction contrary to their motion, or in the direct path of the aërial current,—the former has been denominated by Poullet,[1] propagation by *aspiration;* the latter, propagation by *impulsion.* The aspiration-wind blows before it is felt in a place to windward, the cause existing to leeward. Franklin likens it to the flow of water in a canal which had been stopped up by a gate—all the water moves through the gate, but the motion is propagated from the sluice backwards.[2] A remarkable illustration of an aspiration-wind was observed on the 12th July 1829, in North America. While the bells were ringing for church-service at Albany, a violent gust blew over the town from the S.E. This wind was felt in New York, which lies to the south of Albany, about an hour later, when the service had proceeded some time. It thus originated to the north of Albany, where the pressure of the atmosphere must have been diminished, and extended to the south, in a direction contrary to its motion.[3] Franklin[4] mentions a case in point—it was upon the evening of a lunar eclipse in the year 1740, about 7 P.M.; a violent N.E. wind blew at Philadelphia, and at 11 P.M. it

[1] Elem. de Phys. ii. 715.

[2] See on this, Mitchell,—Silliman's Journal, vol. xix.

[3] Ann. de Chimie, 1831.

[4] Phil. Letters, p. 389.

was felt at Boston, to the N.E. of the former place. He found, upon a comparison of the several accounts received, that this wind blew an hour later for every hundred miles towards the north-east. The notable hurricane of the 29th November 1836, was propagated by impulsion. It was felt at London at 10 A.M., and reached Amsterdam at 1.5 P.M., Hamburgh at 6, and Stettin at 9.5. Tessier mentions a remarkable storm, accompanied by hail, which began in the S.W. of France on 13th July 1788, and in a few hours reached Holland, travelling at the rate of about forty miles an hour. It passed near Loches at 6.5 A.M., Clermont in Beauvoisis at 9, arriving at Utrecht about 2.5 P.M.

375. Various instruments, as will be noticed hereafter, have been contrived for determining the velocity of wind, but no one yet constructed indicates the speed with absolute precision. The most fallacious mode proposed, is that of measuring the shadow of the cloud;[1] at best it only indicates the velocity of that current by which it is impelled, or the superior force of currents in that region.

376. Winds may be conveniently divided into three classes,—those which are *constant*, or always blowing in the same direction; those which are *periodical*, blowing part of the year in one course, and the other period in a contrary direction; and those that are *variable* or erratic, not included in either of the other classes. The two former are met with, in and about the tropics, the latter in temperate regions.

377. To the first of these classes belong exclusively the *Trade* or *East*[2] *passage* winds,—*les vents alisées*,—which blow, with slight deviations, from the east, over a region more than 50° in breath. They sweep round the globe: in the Atlantic, from the coast of Africa to that of South America; in the Pacific, from Panama to the Philippines and New Holland; and in the Indian Ocean, from Sumatra to the eastern coast of Africa. But it is in the Atlantic that this wind blows without a rival,—in the other oceans, as will be presently observed,

[1] Brice,—Phil. Trans. 1766, vol. lvi. p. 224.

[2] Winds are designated by the cardinal points whence they blow, not by their *setting*. The reverse obtains in describing oceanic currents.

(vide 382), it passes into certain monsoon winds. The trade-wind begins to be felt about the 28th parallel of latitude, and extends as many degrees on each side the equator: the breadth of the tract, is subject, however, to changes with the alternate northern and southern declination of the sun. Thus, when that luminary is north of the line, these constant breezes begin to blow as high as lat. 32°, and the southern limit of the northern trade, advances from the equator as far as N. lat. 12°, sometimes even to lat. 15°; when the sun has receded from the northern hemisphere the breadth of the S.E. trade is considerably greater than that of the N.E. trade, extending from nearly N. lat. 1° to S. lat. 28°, and even 30°. The position of the sun and configuration of the African and American coasts explain these changes.

378. In northern latitudes the trade-wind blows N.E.; in southern latitudes S.E., and so steady is it in its course, when removed from the slightest modifying influence of land, that vessels sailing in the "passage winds" scarcely ever require to change a sail. On the extreme boundaries, and for a few degrees on the northern side of the equator, which is the internal limit of these winds, the ocean is generally calm. This tract, denominated the *calms*, the seaman endeavours to avoid: it is the seat of violent thunder-storms. This zone varies in geographical position according to the season, extending much farther north in August than it does in February.

379. We have already observed that even in the region of the trade-winds, opposing currents exist. Paludan saw clouds floating in a path opposite to the course of the winds mentioned; and Tyerman and Bennet[1] witnessed *three* strata moving in reverse order, the upper and the under in the same direction, and the middle in another—the two former against the wind, the latter with it. The fine ashes emitted by the volcano of Cosiguina, in Guatamala near San Vincente, were in February 1835, carried to the West Indies; they had darkened the sun for five days before they were dispersed in the western current, which blows above the Eastern trades. We would notice another instance, although it did not occur in

[1] Jour. of Voy. and Trav. vol. i. p. 50.

the trade-winds :—during the eruption of Tomboro, in 1815, dust was carried to the islands of Amboyna and Banda, the last of which is about 800 miles to the east of the volcano, and this "although the S. E. monsoon was then at its height."[1] An opposing current must have prevailed above that of the monsoon, into which the fine particles had been projected.

380. About two centuries ago, Descartes assigned the trade-winds to the *inertia* of the aërial molecules ; believing that in the rotation of the earth they did not acquire at the equator its full velocity, and were consequently left to follow with diminished speed. Dr Halley,[2] the other great theorist, imputed a different cause. According to him, the trade-winds arise from the confluence of atmospheric particles upon the receding solar rays. Neither of these hypotheses *alone* is tenable, but by a happy combination of the two, Hadley[3] suggested a plausible theory. The solar beams having elevated the general temperature of the tropics, the density of the atmosphere is consequently lessened, and the colder particles of the air in the temperate and polar regions, push on to maintain the equilibrium. Thus there are established aërial currents, directed on either side towards the equator. As the equinoxial line is approached, these gradually decline from the direction of the earth's rotation, in consequence of the increased velocity of its surface, and their being unable to acquire at once a celerity equal to this augmenting speed—thus they assume a westerly motion. In addition, a powerful equatorial influence arises from the attraction of the sun and moon, as has been proved by D'Alembert, and corroborated by Bacon, Halley, and Gassendi in their observations on storms. The higher temperature of the northern hemisphere, and the fact, noticed by Polybius,[4] that the greatest heat is not exactly over the equator, afford an explanation of the circumstance that the equatorial line is not the internal boundary of these winds ; and as the temperature is more elevated upon the land than over the ocean within the tropics, this

[1] Crawfurd,—Lyell's Princip. of Geol. ii. 315.

[2] An Historical Account of the Trade-Winds and Monsoons observed in the Seas between and near the Tropics, 1686.

[3] Phil. Tr. 1735.

[4] Geminus, Isog. in Aratum. cap. 13; Strabo,—Geogr. lib. ii.

accounts for the influence of the former in producing slight deviations in the course of the passage winds. From the convergence of two great atmospheric currents near the equator, there is derived as a corollary, an explanation of those currents moving in opposite directions, which we have illustrated by the motion of the clouds and volcanic dust. The rarefied molecules of air naturally rise through their diminished weight, till the cold of the higher regions diminishes their elasticity; but as they cannot fall, neither can they remain at rest, for the operation is progressive, and others obedient to the same law are rushing on from below, they pass to the side,—thus they diverge from the internal limits of the trades, blowing to the west, till, about the 30th parallel, they sink to the lower strata of the atmosphere and give rise to the S.W. winds of the northern latitudes, and the N.W. winds of the southern hemisphere.

381. The *monsoon*, which was known to Pliny,[1] is a periodical wind, blowing, with occasional calms, half the year from the S.W., and the other six months from the N.E. Its appellation has been derived from an early navigator,[2] but more correctly, the name, according to Marsden, is the same with the Arabic and Malay word *moussin*, a season.[3] Arrian[4] mentions, that Hippalus was the first who entrusted his vessel to this wind, and sailed direct to India from the Straits of Babel-Mandeb; but if the opinion of Bochart[5] is correct, that Ophir was on the eastern coast of Africa, and, according to Bruce,[6] the modern Sofala, it follows that in the reign of Solomon, vessels were borne with "flowing sails and without delay or impediment" by the S.W. monsoon, a thousand years before Hippalus lived. This, however, does not invalidate the statement of Arrian, for other localities have been proposed for the site of ancient Ophir, and the opinion of Bruce has

[1] Hist. Nat. lib. vi. cap. 23.

[2] Varenii Geog. Generalis, c. xx.

[3] Marsden has shewn that the Malay tongue is derived from the Sanscrit, and has many words in common with that language,—Asiat. Res. iv. 217.

[4] Periplus of the Red Sea.

[5] Geog. Sacra, fol. 1646.

[6] Trav. vol. ii. p. 357; D'Anville,—Dissert. sur le pays d'Ophir; Robertson,—India; Horne,—Introd. to Script. vol. iii. p. 607.

been met by Doig,[1] who assigns its position on the western coast of Africa, and places Tarshish in Andalusia.

382. The influence of the monsoon extends from the Chinese Sea to the mouth of the Indus. This wind blows from April to October from the S.W., and from October to April from the N.E.—which, it will be observed, is the direction of the trades. The velocity of the monsoon is much greater than that of the passage winds described, so much so, that vessels sail under diminished canvas, while in the trade-winds, which resemble gentle breezes, every sail is spread, and the ship glides calmly yet speedily onwards. The N.E. monsoon does not blow beyond the first parallel of southern latitude, though in some places it is felt a degree farther to the south ; the S.W. monsoon begins to blow a little north of the line, therefore the equator, with a slight exception in favour of the former, may be considered the southern limit of these winds. In the Indian Ocean, however, we meet with two other periodical winds, the S.E. and N.W. monsoons. The limits of these local winds may be said to be from the equator, or slightly north of that line to the S. lat. 13°. The first of these monsoons blows when the sun is north, and the second when it is south of the equator. The connexion between the S.E. monsoon and the S. E. trade-wind is apparent ; it may, therefore, be correctly said, that in the Pacific Ocean, as in the Atlantic, we meet with the trade-winds.

383. The S.W. monsoon is due to the rarefied air of Eastern Asia, caused by the sun's being north of the equator ; the N.E. may be explained, as we have accounted for the trade-winds. The peculiar configuration of the land in the southern hemisphere, between the eastern coast of Africa and the western shores of America, and the physical characters of these great continents, determine the epoch and course of these winds. As the first blowing of the monsoon depends much upon the declination of the sun and the physical features of the locality, it follows, that this wind is not experienced at the same time upon the whole surface of the globe over which it extends.

384. The approach of the monsoon from the S.W., or the

[1] Essay on Situation of Tarshish and Ophir, 4to.

wet monsoon of India, is thus described by Elphinstone:[1]—"Its approach is announced by vast masses of clouds that rise from the Indian Ocean, and advance towards the north-east, gathering and thickening as they approach the land. After some threatening days, the sky assumes a troubled appearance in the evenings, and the monsoon in general sets in during the night. It is attended by such a thunder-storm as can hardly be imagined by those who have only seen that phenomenon in a temperate climate. It generally begins by violent blasts of wind, which are succeeded by violent floods of rain. For some hours, lightning is seen almost without intermission, sometimes it only illuminates the sky, and shews the clouds near the horizon; at other times it discovers the distant hills, and again leaves all in darkness; when in an instant it reappears in vivid and successive flashes, and exhibits the nearest objects in the brightness of day. During all this time, the distant thunder never ceases to roar, and is only silenced by some nearer peal, which bursts on the ear with such a sudden and tremendous crash as can scarcely fail to strike the most insensible heart with awe. At length the thunder ceases, and nothing is heard but the continued pouring of the rain and the rising of the streams. The next day presents a gloomy spectacle, the rain still descends in torrents, and scarcely allows a view of the blackened fields; the rivers are swollen and discoloured, and sweep down along with them the hedges, the huts, and the remains of the cultivation which was carried on during the dry season, in their beds.

"This lasts for some days, after which the sky clears and discovers the face of nature changed as if by enchantment. Before the storm the fields were parched up, and except in the beds of the rivers, scarcely a blade of vegetation was to be seen. The clearness of the sky was not interrupted by the appearance of a single cloud, but the atmosphere was loaded with dust, a parching wind blew like a blast from a furnace, and heated wood, iron, and every solid material, even in the shade, and immediately before the monsoon, this wind had been succeeded by still more sultry calms. But when the

[1] Account of Cabul and its Depend. in Persia, ch. v. p. 126.

first violence of the monsoon is over, the whole earth is covered with a sudden but luxuriant verdure: the rivers are full and tranquil; the air pure and delicious; and the sky is varied and embellished with clouds. The effect of this change is visible in all the animal creation, and can only be imagined in Europe by supposing the depth of a dreary winter to start at once into all the freshness and brilliancy of spring. From that time the rain falls at intervals for about a month, when it comes on again with great violence, and in July the rains are at their height: during the third month they rather diminish, but are still heavy, and in September they gradually abate, and are often suspended till near the end of the month, when they depart amid thunder and tempests as they came." The monsoon of October 1846, opened at Madras on the 21st with much impetuosity, and in twenty-four hours, 17.5 inches of rain were found in the ombrometer.[1]

385. The *sea and land breezes* are diurnal winds, arising from causes which we have already referred to and explained. They are best studied in tropical climes, for there the exciting cause acts with greatest power. They are altogether due to solar influence: the land being heated by day more than the sea, the air above the former is more highly rarefied than that over the latter, hence a current from the sea, or a sea-breeze, is established; at night the reverse is the case, for by terrestrial radiation the ground becomes colder than the water, and a land-wind blows to preserve the equilibrium of atmospheric forces.

386. Captain Dampier[2] thus graphically describes these breezes. "These sea-breezes do commonly rise in the morning about 9 o'clock, sometimes sooner, sometimes later. They first approach the shore so gently, as if they were afraid to come near it; ofttimes they make some faint breathings, and, as if not willing to offend, they make a halt, and seem ready to retire. I have waited many a time, both ashore to receive the pleasure, and at sea to take the benefit of it.

"It comes in a fine, small, black curl upon the water, when as all the sea between it and the shore not yet reached by it

[1] The Times. [2] Voyages, vol. ii.

is as smooth and even as glass in comparison. In half an hour's time after it has reached the shore, it fans pretty briskly, and so increaseth gradually till 12 o'clock; then it is commonly strongest and lasts so till 2 or 3, a very brisk gale. About 12 at noon it also veers off to sea two or three points, or more in very fair weather. After 3 o'clock, it begins to die away again, and gradually withdraws its force till all is spent, and about 5 o'clock, sooner or later, according as the weather is, it is lulled asleep and comes no more till the next morning.

"These winds are as constantly expected as the day in their proper latitudes, and seldom fail but in the wet season. On all coasts of the main, whether in the East or West Indies, on Guinea, they rise in the morning and withdraw towards the evening; yet capes and headlands have the greatest benefit of them, where they are highest, rise earlier and blow later.

"Land-breezes are as remarkable as any winds that I have yet treated of: they are quite contrary to the sea-breezes; for these blow right *from* the shore, but the sea-breeze right in *upon* the shore; and as the sea-breezes do blow in the day and rest in the night, so on the contrary, these do blow in the night and do rest in the day, and so they do alternately succeed each other. For when the sea-breezes have performed their offices of the day, by breathing on their respective coasts, they in the evening do either withdraw from the coast, or lie down to rest. Then the land-winds, whose office is to breathe in the night, moved by the order of Divine impulse, do rouse out of their private recesses and gently fan the air till the next morning; and then their task ends, and they leave the stage.

"There can be no proper time set when they do begin in the evening, or when they retire in the morning, for they do not keep to an hour; but they commonly spring up between 6 and 12 in the evening, and last till 6, 8, or 10 in the morning. They both come and go away again earlier or later, according to the weather, the season of the year, or some accidental cause from the land; for in some coasts they do

rise earlier, blow fresher, and remain later, than on other coasts, as I shall shew hereafter.

"These winds blow off to sea, a greater or less distance according as the coast lies more or less exposed to the sea-winds; for in some places we find them brisk three or four leagues off shore, in other places not so many miles, and in some places they scarce peak without the rocks, or if they do sometimes in very fair weather make a sally out a mile or two, they are not lasting, but suddenly vanish away, though yet there are every night as fresh land-winds ashore at those places, as in any other part of the world.

"Indeed, these winds are an extraordinary blessing to those that use the sea in any part of the world within the tropics; for as the constant trade-winds do blow, there could be no sailing in these seas; but by the help of the sea and land breezes, ships will sail 200 or 300 leagues, as particularly from Jamaica to the Lagune of Trist, in the Bay of Campeachy, and then back again, all against the trade-wind.

"The seamen that sail in sloops or other small vessels in the West Indies, do know very well when they shall meet a brisk land-wind, by the fogs that hang over the land before night; for it is a certain sign of a good land-wind to see a thick fog lie still and quiet, like smoke over the land, not stirring any way; and we look out for such signs when we are plying to windward. For if we see no fog over the land, the land-wind will be but faint and short that night. These signs are to be observed chiefly in fair weather; for in the wet season fogs do hang over the land all the day, and it may be neither land-wind nor sea-breeze stirring. If in the afternoon, also, in fair weather, we see a tornado over the land, it commonly sends us forth a fresh land-wind.

"These land-winds are very cold, and though the sea-breezes are always much stronger, yet these are colder by far. The sea-breezes, indeed, are very comfortable and refreshing; for the hottest time in all the day is about 9, 10, or 11 o'clock in the morning, in the interval between both breezes; for then it is commonly calm, and people pant for breath, especially if it is late before the sea-breeze comes, but afterwards the

breeze allays the heat. However, in the evening again, after the sea-breeze is spent, it is very hot, till the land-wind springs up, which is sometimes not till 12 o'clock or after."

387. *Mountain-breezes.* M. Fournet has noticed, from observations among the Alps, a regular succession of upward breezes during the day, and downward breezes throughout the night, explicable, as he thinks, by the warming influences of the sun upon the mountain-top, before the valley has received calorific impressions sufficiently powerful to determine a descending current. As the plain warms during the day, and gradually becomes more heated than the mountain, the current is inverted, and there blows a descending nocturnal breeze. These winds are subject to peculiarities depending upon the contour of the place, and have received local names; thus, they are called "thalwind, pontias, vesine, solore, vauderou, rebas, vent du Mont Blanc, aloup du vent."

388. The *Etesiæ* (ἔτος, a season) of Cæsar, are periodical winds, blowing during the dog-days upon the Egyptian coasts, thereby preventing ships from leaving Alexandria; and in the months of March and April from the south-west: the latter have been termed *Ornithian winds,* from their assisting the migratory species of the feathered tribes in their passage over the Mediterranean. To the Etesian winds—the *Meltiem* of the Turks—Egypt owes much of its fertility, for they bear the vapours of the Mediterranean across that country to the lofty mountains of Abyssinia, where they are precipitated in deluges of rain, and thus produce the flooding of the Nile.[1] When the sun approaches the tropic of Cancer, the winds begin to blow regularly from the north; in June their direction is N. and N.W., and in July generally northerly; in August and September, they blow due north, and towards the end of the latter month they veer to the east; in December, January, and February, when the sun has passed the equinoxial line, they are variable, and often tempestuous, generally blowing N.E., N., and N.W. About the end of February, and during March and April, they blow from the southern points of the windrose; in May they blow from the east, and in the suc-

[1] Agatharchides,—Diodorus, i. 41.

ceeding month resume the order described. Bruce[1] mentions having witnessed, in June 1768, numbers of thin white clouds borne rapidly from the south, in a direction contrary to that of the Etesiæ, shewing the existence of opposing currents in these winds. These upper currents, which are supposed to blow from April to July, carry with them humid vapours which descend in Persia, and thereby elevate the waters of the Euphrates.

[1] Trav. in Abyssinia.

CHAPTER XVI.

389. The Simoom, Samiel or Khamsin. 390. Described by Fraser. 391. By Bruce. 392. By Lamartine; Denham. 393. Sandwind of the Desert. 394. Loss of the army of Cambyses; Narrow escape of that of Alexander. 395. Cause of death by the Simoom. 396. Pillars of Sand in the Desert. 397. Harmattan. 398. The Sirocco. 399. Electrical Phenomena. 400. Luminous Precursors. 401. Solano; Libéchio; Ponente.

.... "Like the wind,
The red-hot breath of the most lone Simoom,
Which dwells but in the desert, and sweeps o'er
The barren sands which bear no shrubs to blast,
And revels o'er their wild and arid waves,
And seeketh not, so that it is not sought,
But being met is deadly."

Manfred, act iii. sc. i.

389. The *Simoom*, or hot poisonous wind of the desert, is recognised under the following terms,—Simūn, Samiel, Sambuli, Harrour, and Khamsin. If the statements of travellers are credible, this wind is one of the most dreaded and dangerous phenomena of nature, bringing discomfort, disease or death, to him who, unhappily, may have inhaled the blast: but, doubtless, the accounts received, are in some instances much exaggerated, due discrimination not having been made in distinguishing between the effects of the wind *per se*, and those produced by it upon a body exhausted by fatigue and parched with thirst. Of the simoom, Rifaud[1] thus writes:—"Lorsque cet état de l'atmosphère n'est que faible, il cause

[1] Tableau de l'Egypt et de la Nubie, p. 8.

un mal-aise général, dont tous les êtres organisés se ressentent; à un degré plus intense, il rend malade, et peut même causer la mort." It blows over the deserts of Africa and Asia, and as it commonly prevails before and after the equinox, it has been called by the Egyptians the *Khamsin*,[1] or *wind of forty days.* Its motion is rapid, lasting sometimes for three days, though generally its force is expended in less than one. It withers, and dries up all moisture, in its passage. Volney[2] compares its heat to that of the *drawing* of an oven, but it is not intolerable till it has continued some hours. Its approach is indicated by a redness in the atmosphere, which loses its serenity, and assumes a portentous appearance; the sun withdraws his brilliancy, and shines with lurid brightness,

> —— "that crimson haze
> By which the prostrate caravan is aw'd,
> In the red desert, when the wind 's abroad."
> MOORE,—*Lallah Rookh.*

Burckhardt[3] of Bâle observes, that the air seems in a state of combustion, assuming various tints of red, blue, and yellow; the latter predominating according to the nature of the dust and sand carried by it into the atmosphere; he notices likewise, that it blows not close to, but a little above, the ground.[4] Count Wenceslaus Rzewusky says, the epoch of the Samieli corresponds with the remarkable variation of the Nile, viz.,—between the summer solstice and the winter equinox; and he observes, that the first effect produced by it on man is a copious perspiration more viscous than natural, caused probably by the uneasiness and difficulty of breathing experienced. His explanation of the wind is untenable. A wind like the khamsin, scorching vegetation and blistering the skin, is mentioned by Temple,[5] as having been felt during the summer at St Jago del Estero, in South America.

390. Fraser,[6] in describing the provinces of Persia, observes, that the deserts traversed between Noormanshir in Kerman

[1] Derived from the Arabic. [2] Voy. en Syrie, i. 4; Trav. ii. 61.
[3] Trav. p. 204. [4] Vide Rifaud,—Tableau; Anti,—Obs. on Egypt.
[5] Temple,—Trav. in Peru, vol. ii. p. 484. [6] Persia, p. 96,—Ed. Cab. Lib.

and Nooskee, "like others in these countries, at all times perilous, are in the hotter months frequently visited by blasts of the simoom, which crack and shrivel up the skin and flesh, occasioning all the agony of scorching; while, from the gaping rents, the dark and distempered blood pours out in quantities that soon occasion death. In some cases, life seems at once dried up, while the corpse, changed to a putrid mass, separates limb from limb on being touched. The only method of avoiding this pestilential vapour, the approach of which cannot always be foreseen, is to fall upon the earth, covering the body with whatever garments may be at hand till the blast pass by."

391. Bruce thus describes a simoom which he felt in the desert: "At 11 o'clock, while we contemplated with great pleasure the rugged top of Chiggre, to which we were fast approaching, and where we were to solace ourselves with plenty of good water, Idris our guide cried out with a loud voice,—Fall upon your faces, for here is the simoom. I saw from the S.E. a haze come, in colour like the purple part of the rainbow, but not so compressed or thick. It did not occupy twenty yards in breadth, and was about twelve feet high from the ground. It was a kind of blush upon the air, and it moved very rapidly; for I scarcely could turn to fall upon the ground with my head to the northward, when I felt the heat of its current plainly upon my face. We all lay flat on the ground as if dead, till Idris told us it was blown over. The meteor or purple haze which I saw was indeed passed, but the light air that still blew was of heat to threaten suffocation. For my part, I found distinctly in my breast that I had imbibed a part of it, nor was I free of an asthmatic sensation till I had been some months in Italy at the baths of Poretta, near two years afterwards." This simoom lasted nearly six hours, and left the party greatly exhausted. The same traveller mentions two others, but they did not differ materially from that described.

392. Lamartine tells us that he and his party were exposed to a simoom. The fifth day, after passing the night under the tents of El Henaldi, he says: "We rose with the sun and went out to saddle our dromedaries. What was our amazement to

find them with their heads plunged in the sand, whence they could not be withdrawn. The Bedouins of the tribe informed us, that the circumstance presaged the samiel, which would not long delay its destructive course, and that we could not advance without meeting certain death. We hastened to adopt all the precautions enjoined us. That morning, all was tumult in the camp ; every one endeavouring to provide for the safety of his beast, and then precipitately retiring for protection to the tent. We had scarcely time to secure our beautiful horses before the storm began. Fierce gusts of wind were succeeded by clouds of red and burning sands, whirling impetuously, and overthrowing or burying under their drifted mounds whatever they encountered. If any part of the body is accidentally exposed to its touch, it is scorched, as if by a hot iron. The water became hot, and the temperature of the tent exceeded that of a Turkish-bath. The simoom lasted ten hours in its greatest fury, and then for the following six gradually sunk. Another hour and we must all have perished. When at length we could venture out, a fearful spectacle awaited us ; five children, two women and a man were stretched dead on the burning sand, and several Bedouins had their faces blackened and entirely calcined, as if by a furnace. We thanked the Lord that we had been preserved." Thevenot, in the 17th century, mentions two instances of caravans which in a single night lost some hundreds of their numbers by this cause.[1] It is observed by Major Denham, who, in 1821, accompanied the traveller Clapperton, that "the overpowering effect of a sudden sand-wind, when nearly at the close of the desert, often destroys a whole Kalifa, already weakened with fatigue. The spot was pointed out to us, strewed with bones and dried carcasses where the year before fifty sheep, two camels, and two men, perished from thirst and fatigue when within eight hours march of the well which we were anxiously looking for." Nevertheless the statement of travellers, that this

[1] Vide Ignatius Pallme,—Trav. in Kordofan ; Jackson,—Jour. overl. to India : Morier,—Sec. Jour. p. 43 ; Hasselquist,—Trav. ; Relandi,—Palestina, tom. i. 378–391 ; Pareau,—Antiq. Heb. ; Schalzii Arch. Heb. 9-16 ; Savary,—Let. on Egypt, 1785 ; Stephen,—Persia ; &c.

wind is so injurious, the unfortunate Burckhardt[1] could not find, from the accounts of the Arabs, that it is in reality so fatal. He mentions having experienced one at Esne in Upper Egypt in May 1813, when the thermometer in the shade rose to 121° F., and again in June, in going from Esne to Siout. He experienced another in June 1815, between Tor and Suez, the heat of which evaporated from the water-skins one-third of their contents.

393. Denham again writes: "The sand-wind we had the misfortune to encounter in crossing the desert, gave us a pretty correct idea of the dreaded effects of these hurricanes. The wind raised the fine sand with which the extensive desert was covered, so as to fill the atmosphere, and render the immense space before us impenetrable to the eye beyond a few yards. The sun and clouds were entirely obscured, and a suffocating and oppressive weight accompanied the flakes and masses of sand which, I had almost said, we had to penetrate at every step. At times we completely lost sight of the camels though only a few yards before us. The horses hung their tongues out of their mouths and refused to face the clouds of sand; a parching thirst oppressed us, which nothing alleviated."

The sand-wind of the desert is the samiel in squalls, and much more dangerous than the simoom. To avoid the latter, the traveller flings himself upon the ground to let the blast move by; and instinct teaches the beast of burthen to plunge its nostrils in the sand. When the squall arises, and clouds of sand float upon the whirlwind, the danger presses on every side, and the weary traveller resting on the leeside of his camel, risks his being instantaneously enveloped in a mound of shifting sand. These sand-drifts of Africa, in their western course, have entombed cities and temples, buried colossal figures of ancient art, and are now making aggressions on the fertile soil of Egypt. They remind us of the overwhelming of towns nearer home—of the *dunes* of sand which have encroached upon the eastern coast of England, and swallowed up the ancient village of Eccles, in Norfolk, of which there still remains a portion of the church tower; and

[1] Travels, p. 204.

of the loss of the village near St Pol de Leon, in Brittany, which was so completely covered, that only the spire of the church remained to point out the place of the catastrophe.[1] Dunes of sand, which are sometimes blown like showers of snow, have recently been discovered in Australia, separating the long and narrow lake of Coorong from the Southern Ocean.[2]

394. The classical reader will recall the narrative of Herodotus, of the loss of the army of Cambyses in the desert of Lybia. This ambitious prince having routed the Egyptians, and heard of the reputed wealth of the long-lived Macrobians, resolved to make war against that Ethiopian race. Having reached Thebes, he separated his army into two divisions, directing 50,000 of his troops to advance against the Ammonians, and pillage the temple of Jupiter Ammon.[3] It appears that they reached the Lybian Oasis, but they never returned, for a sand-wind rose from the south, near to the temple of Ammon, and in its violent blast overwhelmed the army, utterly destroying them, so that no one ever returned to tell the tale. Such, too, was nearly the fate of the soldiers of Alexander, about two centuries thereafter, while they crossed the desert from Memphis to Jupiter Ammon, a twelve-days' journey.[4] The foliage of the oasis which waved in the wind in the days of Cambyses and Alexander, may have mouldered in the ground—the heathen temple may be a ruin[5]—but the luxuriant palm still shades that verdant spot, and gives to the oasis of Seewah, if aught, a deeper interest now than then. Belzoni[6] mentions having met with a number of *tumuli* in the desert, which he supposes to have been raised over the army of Cambyses. Yasasin, King of Yemen, in Arabia Felix, —the successor of Belkis, according to the Arabs, the fa-

[1] Mém. de l'Acad. des Sc. de Paris, 1772.

[2] Mr M. T. Burr,—North Brit. Rev. No. xi. p. 245, Nov. 1846.

[3] Herodot.—lib. iii. cap. 25. 26; Pliny,—lib. v. 9.

[4] Quint. Curt. lib. iv. cap. 7; Plut.—Alex. p. 687.

[5] Visited in 1793 by Browne,—Trav. in Africa, &c., 1792–1798. 4to.; by Horneman in 1798; by Drovetti 1820; and in same year by Baron Minutoli. Vide Rennell,—Geog. Herod. vol. ii. p. 230, 2d Ed.

[6] Nar. 3d ed. vol. ii. p. 179.

mous Queen of Sheba,—is said to have carried his army into the unexplored deserts of the west; but being overtaken by the whirlwinds of erratic sands, he was forced to return with the loss of a portion of his men. There, he raised a brazen statue to mark the limit of his march, and as a beacon to warn of the dangers which might befal those who attempted to go beyond it. Sir Robert Porter[1] conjectures, that the deadly samiel which blows in gusts with great rapidity, was in the hands of Jehovah the agent of the destruction of the army of the impious Sennacherib, when it was encamped under Rabshakeh, against Jerusalem. In Scripture[2] reference seems made to the same wind,—"Neither shall the sun light on them, nor *any heat*," or as a French translator renders it, a *burning wind.*

395. Death may proceed from the effects of these winds in producing congestion of the lungs resembling pulmonary apoplexy, or by that species of apoplexy frequently the consequence of intense heat,—the *coup de soleil.* Rzewusky[3] observes, that death may arise not only from asphyxia, but from the great debility induced; and that in the former case, nature sometimes relieves the sufferer by *hæmaturia.* The Count's interpreter, Rossel, was thus saved.

396. *Pillars of sand* in the desert, the *zôba'ah* of the Egyptians. Bruce[4] thus describes this remarkable phenomenon which he witnessed in the desert of Nubia. "At one o'clock we alighted among some acacia trees at Wady-el-Halboub, having gone twenty-one miles. We were here at once surprised and terrified by a sight surely one of the most magnificent in the world. In that vast expanse of deserts, from W. to N.W. of us, we saw a number of prodigious pillars of sand at different distances, at times moving with great velocity, at others stalking on with majestic slowness. At inter-

[1] Travels in Persia, ii. 230.

[2] Rev. ch. vii. v. 16; Critici Sacri, sivi Annotata doct. Virorum in vet. et Nov. Test. Amsterd. 1698, vol. ix. The original suggests, however, possibly a different meaning,—a burning fever, καὐμά.

[3] Jour. to Palmyra, &c., Lit. Jour. 1821, vol. i. p. 21.

[4] Trav. vol. iv. p. 553; Belzoni,—Nar. vol. i. p. 304; Clarke,—Trav. Egypt; Burckhardt,—Trav.; Lane,—Mod. Egyptians, 3d ed. part i. ch. x.; &c.

vals we thought they were coming in a very few minutes to overwhelm us, and small quantities of sand did actually more than once reach us; again they would retreat, so as to be almost out of sight, their tops reaching the very clouds; then the tops often separated from the bodies, and these, once disjoined, dispersed in air and did not appear more; sometimes they were broken in the middle as if they were struck by large cannon shot. At noon they began to advance with considerable swiftness upon us,—the wind being very strong at north. Eleven ranged alongside of us, about the distance of three miles; the greater diameter of the largest appeared to me at that distance as if it would measure ten feet. They retired from us with a wind at S.E.; leaving an impression on the mind to which I can give no name, though surely an ingredient in it was fear, with a considerable deal of wonder and astonishment. It was in vain to think of fleeing; the swiftest horse would be of no use to carry us out of this danger, and the full conviction of this rivetted me to the spot." Burckhardt mentions having seen these sand-pillars in the desert, and on the banks of the Euphrates. Adanson[1] gives an account of the same appearance seen by him, crossing the Gambia from the Sahara; the pillar was 250 feet high, and about three in thickness; it radiated heat at the distance of a hundred feet, and left behind the odour of nitre. Lane measured one at Thebes and found its height was 750 feet. Caillié, describing the same phenomenon, says, "One of the largest of these pillars of sand crossed our camp, overset all the seats, and whirling us about like straws, threw one of us on the other in the utmost confusion. We knew not where we were, and could not distinguish any thing at the distance of a foot. The sand wrapped us in darkness like a fog, and the sky and the earth seemed confounded and blended in one. Whilst this frightful tempest lasted, we remained stretched on the ground motionless, dying of thirst, burned by the heat of the sand, and buffeted by the wind. We suffered nothing, however, from the sun, whose disc, almost concealed by the clouds of sand, appeared dim and deprived of its rays."

[1] Africa, p. 414.—Ed. Cab. Lib.

397. The *Harmattan* wind next claims our attention. Its name is Fantee,—*Aherramanta,*—and is the same with that which the French and Portuguese denominate the *north-east wind of Africa.* It is a periodical wind blowing from the arid sands in the centre of that continent, to the Atlantic Ocean. It is well described by Norris.[1] From Cape de Verde, in N. lat. 15° to Cape Lopez in S. lat. 1°, the harmattan blows easterly during December, January, and February. It blows at periods which bear no relation to time or tide, continuing from one to fifteen days, and recurring generally three or four times in the season. Its force is less than that of the sea-breeze, but stronger than the land-breeze. A thick fog accompanies the wind, and the sun looks red. This wind, according to Dr Lind,[2] is malignant, but others consider it salubrious; this diversity of opinion, doubtless, arises from the opposite characters of diseases exposed to its effects. No dew falls while it blows, and vegetation is parched by its aridity. Dust borne by a violent harmattan to a distance of 700 miles, fell upon the Clyde, East Indiaman, on the night of January 19. 1826, in N. lat. 10° 40′ and W. long. 27° 41′. Jackson, in N. lat. 30°, and long. 10° 30′, collected when twenty leagues from land, a wine-glassful of sand which had fallen upon deck after having been borne on the wind from Africa. Again, on the 29th March 1821, while in N. lat. 11° 3′ and W. long. 22° 5′—300 miles from land—sand was found upon the rigging of a ship bound for the East Indies.[3]

398. The *Sirocco,* or Maledetto levante,—the *Plumbeus Auster* of Horace, and *Vulturnus* of other ancient authors,—is probably the wind of which Hannibal availed himself at the famous battle of Cannæ, by directing the position of his army, so that it blew directly in the faces of his enemy. It is a periodical wind, blowing about Easter, in Italy and Dalmatia from the S.E. by S. It generally continues twenty days, and usually ceases at sunset. Blowing from the parched sands of Arabia and Lybia, it oppresses by its heat, and crossing the Mediterranean becomes disagreeably humid; respiration is

[1] Phil. Tr. vol. lxxi.
[2] Dis. in Hot Clim. incid. to Europeans.
[3] Ed. Phil. Jour. vii. 404.

uneasy, and fires are said to burn languidly, as if the supply of oxygen was diminished. Brydone[1] thus describes a sirocco which he experienced at Palermo. "The 6th and 7th of July 1770 were uncommonly cool, the mercury never having been higher than 72°.5 F., and although the sirocco is said to have set in early on Sunday morning the 8th, the air in our apartments, which are very large and with high ceilings, was not the least affected by it at 8 o'clock when I rose. I opened the door without having any suspicion of such a change, and indeed I never was more astonished in my life. The first blast of it on my face felt like the burning steam from the mouth of an oven. I drew back my head, and shut the door, calling out to Fullarton, that the whole atmosphere was in a flame. However, we ventured to open another door that leads to a cool platform where we usually walk; this was not exposed to the wind; there I found the heat much more supportable than I could have expected from the first specimen I had of it at the other door. It felt something like the subterraneous sweating stoves at Naples, but still much hotter. I went to examine the thermometer, and found the air in the room as yet so little affected that it stood only at 73°. I took it out to the open air, when it immediately rose to 110°, and soon after to 112°; and I am confident that anywhere within the city, it must have risen several degrees higher. The sun did but once appear during the whole day, otherwise I am persuaded the heat must have been insupportable. This extraordinary heat continued till 3 P.M., when the wind changed."

399. Mr Ronalds made some observations at Palermo during the sirocco, from which he concluded that the electricity is then always positive. Volta's electrometer indicated from 5° to 21°; and the electric tension was observed to increase almost progressively from sunrise till about 3 P.M., when it gradually declined till sunset, a phenomenon, the opposite of what occurs in serene weather. Dr Hemmen[2] and Dr Johnson[3] have some interesting observations upon this wind. Dr

[1] Tour in Sicily and Malta.

[2] Med. Topog. of Mediter.

[3] On Trop. Climates, p. 280.

Benza, an Italian, mentions having collected an almost impalpable powder of red micaceous sand in Sicily, after a sirocco followed by rain. This sand fell abundantly at Palermo in 1811. In Corfu the true sirocco is termed the *black sirocco.* This wind is often succeeded by the Tramontana, or N.E. wind, which blows from the frozen summits of the Apennines, producing much sickness and mortality.

400. It is mentioned by Dodwell,[1] that previous to the blowing of the sirocco, lights are seen flitting about the precipitous cliffs of the Acroceraunian Mountains, probably owing to the presence of carburetted hydrogen. That flames produced by the ignition of gaseous fluids, arising from the ground and depending upon its geological structure, existed both in ancient and modern times, we have the testimony of Dion Cassius, Vitruvius, Anacharsis,[2] and Strabo,[3] who mentions the instance at Nymphaion in Apollonia ; of Pliny,[4] who describes that of the celebrated Mount Chimæra in Lycia, now called Taktalu, situated near to Deliktash in Asia Minor, and described by Beaufort,[5]—the triple monster of the poets, as sung by Homer,[6] Hesiod,[7] Lucretius,[8] and others, conquered by Bellerophon ; of Photius,[9]—that of Olympus ; of Ctesias,[10] —that near Phaselis, on the eastern coast of the same place, which probably is the same as that mentioned by Pliny ; of Pausanius,—that of Bathos in Arcadia ; of Tournefort[11]—one in Greece ; of Clarke,[12] Holland,[13] and others. We might refer to the spring of inflammable gas at Samos, the birthplace of Pythagoras ; to the famous "field of fire" at Baku, on the Caspian, described by Humboldt, Hanway, and others ;[14] to

[1] Classic. and Topog. Tour in Greece, 4to, 1819.

[2] Trav. vol. ii. 424; Ib. vol. v. p. 34,—Eng. Ed. 1791.

[3] Strabo,—Geogr. lib. vii. xiv.

[4] Hist. Nat. lib. ii. c. 106; Seneca,—Ep. 79.

[5] Surv. of Coast of Karamania, 1820, p. 24.

[6] Homer,—Ib. vi.

[7] Theogony, v. 322.

[8] Lucret. v. 903.

[9] Biblioth. Methodius, p. 924.

[10] Ctesias,—Fragm. cap. x.; Ctesiam in app. Herod. Wesseling, p. 860.

[11] Let. 4, 5.

[12] Trav. in Greece, Egypt, and Holy Land, 4th ed. vol. vi. 348, and vii. 462.

[13] Trav. in Ionian Isles, Albania, &c. 1812–15, pp. 416, 518.

[14] Asie Centrale, tom. ii.; Fragm. Asiatiq.; Walpole,—Mem. relat. to Europ. and Asiat. Turkey, 1827, p. 228; Hanway,—Trav. in Persia, vol. i., Account of Brit. Trade over Casp.; Malte Brun's Geog. vol. ii. 60; Engelhardt and Parrot,—Trav. in Crimea and Cauc. in 1815, vol. i.; Forster,—Trav. overland to India.

that called Iwálá-Mukhé in the Punjaub, mentioned by Hügel;[1] to the "fire-springs" at Kiating-fou in China, described by Imbert,[2] and to other places in the same empire, where igneous gases are emitted; to a temple at Chittagong, in Bengal; to the "Pit of the Wind," in a salt-mine at Reine, in Tecklenberg;[3] to that of the Pietra-mala in Bolognese Apennines, about twenty-four miles N.W. from Florence; and to that at Fredonia on Lake Erie, recently described by Lyell.[4]

401. *Solano; Libéchio.* The Solano or *levanter* of Gibraltar pilots, is a variety of the sirocco experienced in Spain, and blowing from the south-east. It is extremely hot, and loaded with impalpable dust. The Spaniard, referring to its physiological effects, quaintly says,—no rogar alguna gracia en tiempo de solano,—ask no favour during the solano. The Libéchio is a southern wind blowing in Italy, and producing effects like those of the sirocco. The *Ponente* is a west wind similar to the classic Favonian breezes, blowing in the Campagna di Roma.

[1] Trav. in Kashmir and Punjáb,—Jervis, p. 44.

[2] Annales de l'Assoc. de la Propagation de la Foi, 1829.

[3] Edin. Jour. of Sc. No. xv. p. 183.

[4] Trav. in Nor. Amer.

CHAPTER XVII.

402. The Whirlwind. 403. Typhoon. 404. Tornado. 405. Remarkable examples. 406. Theory of Espy. 407. Pamperos. 408. Hurricane. 409. Historical Notices. 410. Occurrences in present century. 411. Cuba hurricane: Awful hurricanes of 1846. 412. Hurricane in New South Wales. 413. Great storm of 1703. 414. Theory of the hurricane. 415. Wind-storm of America. 416. Squall. 417. Bize, Bora, Mistral, Tramontana. 418. Tourmente, Guxen. 419. Variable Winds of Temperate Regions. 420. Law of Changes. 421. Circular theory of Storms. 422. Temperature of Erratic Winds. 423. Malign influence.

.... " Sometimes when all seems peace,
Wakes the grim whirlwind, and, with rude embrace,
Sweeps nations to their grave, or in the deep
Whelms the proud wooden world: full many a youth
Floats on his wat'ry bier, or lies unwept
On some sad desert shore!"

BISHOP PORTEUS.

402. The *Whirlwind* is a rapid, impetuous wind, moving spirally, often with destructive violence, uprooting trees and overturning buildings. Its breadth is usually confined, so that its ravages are limited and local. It appears to have an electric origin, the proximate cause being an upward atmospheric current. " In the afternoon," says the late Mr Bennet,[1] " while we were at Kitoor, a tree standing near the palace of the Rajah, was suddenly assailed by the *pisach*, as the Hindoos call it—that is the devil; and truly by an invisible spirit it seemed agitated in the most violent manner, while all the air was calm around. It in fact was a very narrow local whirl-

[1] Jour. Voy. and Trav. vol. ii. p. 362.

wind, which rent the foliage and raised the dust in a spiral column about the tree to a great elevation. In two minutes it was gone, and every branch and leaf remaining, became as still in the course of a few seconds as though nothing had happened to disturb them. Such gusts are not uncommon at this season (April), and are frequently confined in their operations to a circle of a few yards' diameter. Severe thunder-storms with heavy rains, came on about the corresponding hours of the two following afternoons." Bruce[1] mentions a whirlwind which he experienced in a plain about two miles from the village of Nuba, near Basboch on the Nile. It entirely demolished one-half of a hut, scattering the fragments, but left uninjured the other portion of the dwelling; it lifted up a camel, which it threw to a distance, the unfortunate animal sustaining fracture of several ribs; the traveller and two servants were raised and cast down upon their faces, and covered with the red mud of the place, but they were not severely hurt. Morier[2] describes the whirlwind of Persia. A whirlwind of dreadful fury preceded the volcanic eruption of Tomboro, in Sumbawa, described by Sir Stamford Raffles.[3] It swept man and beast into its vortex—prostrated houses, uprooted mighty trees, and strewed them upon the ocean. Upon the 26th of April 1818, a violent whirlwind visited the neighbourhood of London, which has been described by Colonel Beaufoy.[4]

On the 25th October 1820, a whirlwind was experienced in Silesia, where, upon a meadow twenty-seven pieces of linen were being bleached. The doors of a large building were broken down, a heavy cart was completely overturned, the linen was carried sixteen yards above the house, and dropped in a ditch 150 paces off; the weight of the cloth thus borne up was about 650 lbs. avoird., and this was independent of a post measuring six and a half feet long, about one wide, and three inches thick, which was entangled in the skein. One was observed at Dumfries on the 11th May 1847: a dress then lying in a garden at Corbelly Square, was whirled up till

[1] Trav. vol. iv. p. 422; Park,—Trav. p. 135.
[2] Sec. Jour. p. 202.
[3] Hist. of Java, i. 28.
[4] Col. Beaufoy,—Ann. of Phil. xi. 442.

nearly out of sight, and carried to a field half a mile from where it lay.

The following instances indicate the close connexion existing between the whirlwind and waterspout, already referred to. One of them occurred on the 24th June 1823, at Scarborough.[1] It was preceded by boisterous weather of a fortnight's duration, and a low atmospheric temperature. Upon the day mentioned, an appalling thunder-clap was the herald of the whirlwind—now there was a brief repose, and anon the elements were troubled: a dense cloud descending from the S.W. and a lower one moving from the N.E. were brought in contact, apparently by electric attraction. These clouds beat upon each other and rebounded—again they approached, and blended in one dense column; the surrounding clouds rushed whirling to the same centre. This column descended to the earth, and moved from the W.N.W., tearing up trees in its path; it changed its course, and advanced to the east, scattering the sand to a great height, and overturning the bathing machines upon the shore. It passed between the piers, making havoc with the shipping, and raising spray to the height of a ship's top-mast; it crossed the harbour, and rising over the battery in rapid volutions, ascended higher and disappeared. From the great quantity of water raised, and the violent agitation of the waves below the column, many deemed this phenomenon a waterspout: it left no trace of water on the land, nor did it seem more than a dense mass of vapour, violently agitated, and revolving on an axis; there was a continuous roaring sound, but no discharge of lightning. Another and more remarkable storm of a similar kind, occurred on the 6th July same year, at Assonval, six leagues from Boulogne.[2] At 1.5 P.M. the plain of Assonval was darkened by clouds which were rapidly collecting from all points of the compass, and when they had united formed one dense mass wide as the eye could survey: now there descended a dense vapour of a bluish colour, like a reversed cone, which turned rapidly round. This mass of singular aspect separated

[1] Ed. Phil. Jour. vol. ix. p. 398; vol. x. p. 11.

[2] Ib. vol. xi. p. 405; Bulletin Universel. 1824.

from the cloud, and, like a ball, touched the earth and rebounded—there issued from its centre occasional balls of fire, attended by a noise like the rattling of a heavy carriage along a pavement. The wind was impetuous; nothing withstood its fury—the ground was torn up, houses were overturned, stately trees were uprooted and laid in different directions, others were lifted up and carried to a distance, branches were swept into the vortex, and again cast out: thus it raged over several leagues. At Lambre it divided into two—one was dissipated, and the other advanced to Lillers, three leagues further, where it destroyed nearly two hundred trees, and then disappeared. At 3 P.M. all was calm, the thunder was past, and the night was beautiful. Upon the 18th July 1828, between 2 and 3 P.M., a storm was observed to gather, southward of Boston; the atmosphere had been sultry, and now it thundered. Then a small black cloud was observed to descend suddenly, in the shape of a column, and as rapidly a similar cloud appeared to rise from the earth—the two joined and formed a vast black column between the ground and the clouds. This columnar body advanced rapidly from the south to the north-east with a loud rushing noise. At Wyberton Fen it carried up, and to a distance, some manure which two labourers had been spreading on a field—levelled a field of wheat—and in its course drew up a considerable quantity of water which it again deposited. Entering a farm-yard, it threw down a fence and lifted the sheep-hurdles—uncovered a waggon-shed—demolished the end of the building, and injured an adjoining barn. It then carried a heavy cart rapidly to a distance of 120 feet, and a ponderous four-horse roller nearly twenty yards. It passed to another farm, uprooting a tree and destroying some poultry. It now passed over the river Witham, being occasionally elevated and sometimes depressed in its course: it then went towards an adjoining wood, where it divided into two columns, which twisted themselves spirally—one in an ascending, the other in a descending direction—accompanied by a loud noise, flashes of lightning and sulphureous smell, and followed by torrents of rain. In

its zigzag path, it uprooted or destroyed 5000 trees, many of which were strong oaks At Dalderby it destroyed an orchard, and a little to the northwards disappeared in an ascending direction.[1]

On the 29th of July 1833, a whirlwind, unattended by serious consequences, visited Edinburgh. The thermometer was about 75° F. in the shade, and the atmosphere felt sultry, not having a breath of wind to cool it; suddenly about 5 P.M. the thermometer fell 20°, and immediately there rose a violent wind, which for a brief space of time blew furiously, the dust towering above Arthur's Seat like a brown-coloured haze. In the evening all was again quiet, but the air felt chilled under a north-east wind. A disastrous whirlwind was experienced at Rouen[2] on August 19. 1845, which, according to M. Precisier, originated at Houlme, two leagues off. Two violent winds moving in contrary directions met, and there was formed a descending cone having a rotatory motion, which emitted flashes of lightning and was attended by a sulphureous smell. The barometer fell suddenly from 29.66 to 29.13 inches, and the temperature rose several degrees. It passed through a wood, tearing off branches from the trees,—it demolished a cotton factory, but did slight injury to the adjoining houses. The wind moved zigzag, attracted apparently by the machinery. Two other factories were destroyed, and numerous lives were lost: the effects of this whirlwind ceased at Clèves. A curious action for indemnity was raised by the sufferers against the Insurance Companies, which had issued policies providing compensation for loss by lightning—*feu de ciel*, and it was argued against the claim that the storm was *not* electrical. Pouillet, to whom it was referred, decided that electricity had nothing to do with the phenomenon!

403. The *Typhoon* is analogous to the wind which we have just described, and corresponds to the *Senda* of Abyssinia. It blows in the Chinese Seas, between north latitude 10° and 30°, and from the coast of that country to east longitude 150°.

[1] Stamford News, Aug. 9. 1828.

[2] Arago,—Acad. Sc. Aug. 26; Athen. No. 933.

——"Amid the heavens,
Falsely serene, deep in a cloudy speck
Compress'd, the mighty tempest brooding dwells;
Of no regard, save to the skilful eye.
Fiery and foul, the small prognostic hangs
Aloft, or on the promontory's brow
Musters its force. A faint deceitful calm!
A fluttering gale, the demon sends before,
To tempt the spreading sail. Then down at once,
Precipitant, descends a mingled mass
Of roaring winds, and flame, and rushing floods."

THOMSON,—*Summer*, v. 986. *et seq.*

The circular theory of storms about to be mentioned, has been noticed to apply to the typhoon.[1] The wind blows in a spiral curve along an axis, advancing at the rate of about fifteen miles an hour: the breadth of the curves varying from one to two hundred miles. External to the limits of these curves, the atmosphere is violently agitated, and the wind blows as if to a central spot situated in the line of the typhoon's progression. A heavy swell, and clouds gathering in the direction whence it proceeds, together with a falling barometer, warn of the approach of the tempest. With due care the seaman may escape the danger by changing the course of his vessel, but without this precaution he may be borne into the very centre of the storm. This fact was illustrated in July 1847, off Hong-Kong. A typhoon passed over that island and was experienced at sea, about two hundred miles to the eastward, where an Indiaman was dismasted. H. M. S. *Vernon*, by altering her course, ran, so to speak, "under the stern of the typhoon."[2] A typhoon visited Hong-Kong on the 21–26th July 1841, which has been described by Commander Hall.[3]

404. The *Tornado*, correctly so called, is a wind of Africa, experienced in March, or previous to the Harmattan. The name is derived from the Portuguese word *trevado*, a thunderstorm. This wind is for the most part indicated by lightnings and heavy clouds in the east, and by a clear bluish horizon.

[1] Vide Horn-book of Storms,—Piddington and Reid.
[2] Illust. News, Nov. 20. 1847, diagr.
[3] Voy. of Nemesis, Lond. 1844.

Winterbottom observes that the cloud may not at first be larger than the hand, but soon its dimensions are much increased ; the sky darkens in the east, the lightnings are more vivid, and the tempest, working in the troubled regions of the higher air, is preceded by an awful silence. A gentle breeze breaks the stillness, and almost immediately, violent gusts, appalling thunders, and rain in torrents announce the tornado. The storm lasts a few hours, and then subsides ; meanwhile the thermometer falls a few degrees, and the mercury sinks in the barometer. It will be observed, that the tornado is very similar to the typhoon.

405. In 1780, Grenada in the West Indies was visited by a tornado. Unlike similar phenomena, this was to the inhabitants a providential deliverance. Some time before, the *Formica saccharivora*—a species of ant,—appeared in such numbers as to endanger the annihilation of the sugar cane, and the people, after in vain trying many expedients and offering large rewards, were contemplating leaving the island. By this tempest, an Almighty arm accomplished what man with all his appliances had signally failed to overcome—the ant was exterminated ! This leads us to observe that violent commotions in our atmosphere produced by tornadoes, hurricanes, and thunder-storms, are often the means of removing putrid exhalations, the sources of epidemic, and endemic diseases.[1] Hecker mentions that such was the case during the first visitation of the sweating sickness in England. "On new year's day 1486, a violent tempest arose in the S. E., and by purifying the atmosphere relieved the oppression under which the people laboured, and thus, to the joy of the whole nation, the epidemic was swept away without leaving a trace behind :"[2]

> "Not more propitious the Favonian breeze,
> To nature's health, than purifying storms."

About the beginning of the present century, a tornado of awful violence visited Tahiti—a rare phenomenon in that

[1] Chisholm, Clark, Copeland, Devère, Webster, &c,

[2] Epidem. Mid. Ages, p. 186,—Babington ; Hist. of Med. book ii. p. 311

island,—producing unexampled devastation. Famine and universal distress prevailed, before the fields could furnish to the natives their wonted and much-needed produce. In the summer of that remarkable year, 1846, the islands of Sicily and Malta were swept by a similar wind. Two massive iron-bars of the gate of St Antonio were broken, and the gate was opened by its force. About the same time, a violent tornado nearly destroyed the town of Grenada, in Mississippi, killing and wounding many of the inhabitants. A terrific tornado and hurricane swept over Tobago and the windward islands, on the 11–12th October 1847; in the first-named island, 510 houses were destroyed, 250 were injured, and 17 human beings perished. It passed Barbadoes, Grenada, and Trinidad, and was felt at sea between Bermuda and St Thomas. Upon the 1st of May 1848, the British Parliament granted two sums amounting to £55,000, for restoring Tobago to the state it was in, previous to this tempest.

406. Mr W. R. Johnson[1] describing the effects of a violent tornado, which on the 19th June 1835, desolated a portion of the city of New Brunswick, New Jersey, explains the upward force of the wind by the theory of Espy,[2] viz.:—that the disturbance of atmospheric equilibrium, resulted from the liberation of latent heat attending deposition of moisture in the higher regions of the atmosphere, an ascending current being produced by the expansion of the cold dry air above: the expansion in this case being much greater than the contraction from the condensation of the aqueous particles—caloric being furnished during the precipitation more abundantly than the increasing capacity of the expanding air can receive—an upward current is maintained, whose force is proportioned to the difference of the supply and the capacity of the atmosphere for caloric:—vide 414. The *ox-eye* or *bull's-eye* of the Cape of Good Hope is a wind similar to the tornado.

407. *Pamperos.* The pampero is a wind closely allied to the tornado, blowing from the snowy Andes over the pampas of South America, towards Buenos-Ayres, in consequence of

[1] Jour. of Acad. of Nat. Sc. Philadelph. vol. vii.; Ed. Jour. of Nat. Hist. Sept. 1838, p. 160.

[2] Philos. of Storms, 8vo.

the unequal densities of the air over the sea and land: it is an *aspiration* wind. It is met with in summer after sultry weather and a continuance of north winds, and appears to issue from dark and singular-looking clouds in the S.W. The dust carried down by this impetuous wind darkens the sky, adding to the impending danger—thunder and lightning attend, and the barometer falls.

408. *Hurricane.* The hurricane is a wind which blows with the great velocity of about 100 miles an hour, and spreads desolation in the place over which it passes. It is met with chiefly in the tropics, where it rages with greatest fury in the vicinity of land, and where it has been observed to reappear in the same latitudes with singular regularity.[1] In the northern hemisphere, the focus of the storm is in the West Indies; in the southern, about the Mauritius and Rodriguez Islands, to the east of Madagascar. In temperate regions this wind may begin merely as a violent storm, and strengthen to a hurricane, if the physical features of the locality determine local currents into the main stream of moving air.

The hurricane is prognosticated by signs very similar to those which herald the tornado. The portentous calm, the sultry air, the shifting clouds gathering into wild and threatening forms, the almost universal gloom, the darkened sun "shorn of his beams," the troubled flight of birds, and the uneasy motions of the animal creation, forewarn of its approach: the barometer falls rapidly till the violence of the storm is nearly spent, after which it begins to rise—the surface of the mercury heaves in the tube during the commotion of the atmosphere:[2] a deep murmuring sound is heard, a gust is felt and instantly it blows a tempest—the storm gathers in its fury strength, and rages with redoubled violence; the strongest trees bend and break, or are torn up—the oak of centuries snaps across, and like down upon the wings of the wind, is hurried on with incredible speed—the habitations

[1] Physical Atlas.

[2] During a hurricane which blew on the 7th December 1827, when the barometer fell 0.7 of an inch from 10 A.M to 8 P.M., Professor J. D. Forbes observed the convex surface of the mercury heave with great violence to the amount of 0.03 inch. Ed. Jour. of Sc. vol. ix. p. 139.

of man totter and fall, and what the wind fails to overthrow, the floods destroy, for torrents fall hundreds of miles around the vortex of the tempest. It desolates the land and sweeps the ocean. The tornado may add its fury to the hurricane, and with vivid lightnings, appalling thunders, and shifting winds, produce an effect of solemn grandeur and awful fear.[1]

The hurricane, like the whirlwind and typhoon, moves in a circle advancing along an axis, which Colonel Reid supposes to be a curve approaching the parabola. This great circle, according to the same authority, expands in its progress, turning in the northern hemisphere from west by south to east, and from east by north to west; while on the southern side of the line, its revolutions correspond with the direction of the hands of a chronometer. Dove explains the motion as S.E., N.W. in the northern, and N.E., S.W. in the southern hemisphere, *i.e.*, in the North Atlantic Ocean the axis of the storm has a progressive motion from the equator obliquely towards the north pole, while in the Indian Ocean it proceeds from the equator obliquely to the south pole. In the West Indies, the season of the hurricane is from August to October inclusive; in the Indian Ocean, from December to April. From a list of forty-seven hurricanes which have been experienced in the Caribbean Sea and among the West Indian Islands, down to August 1848, we find that one occurred in the month of June, four in July, eighteen in August, twelve in September, and twelve in October.

The rate of progression of the hurricane is not always the same. The Barbadoes storm of 1831, advanced at the rate of 383 miles *per diem;* and the Rodriguez hurricane of 1843, was estimated by Mr Thom to progress during its early stage at from 220 to 230 miles *per diem*, and 50 as it approached the tropics. Piddington[2] calculates the rate of motion in the Bay of Bengal, at from 3 to 39 miles *per hour;* and in the China Sea at from 7 to 24 miles in the same time. Reid and Redfield assume the dilatation, in the Atlantic Ocean, at from 600 to 1000 miles across, and Thom assigns 600

[1] Vide Mosley,—Trop. Dis.

[2] Horn-book of Storms, Calcutta, 1844.

miles as the largest size of a hurricane in the northern part of the Indian Ocean. Hurricanes are attended by *storm waves and currents,* causing inundations on their approaching land. The storm-currents, are circular streams "or the circumferences of rotatory storms."[1]

409. Hurricanes are recorded in Europe in the year 800; on the 17th of January 1207; in October 1250, when there was great loss by the storm-waves both here and in Holland; on the 26th of November 1282, when the Zuyder Zee was formed by the union of Lake Flevo with the ocean; on the 19th of November 1321, when the dykes of Holland were overthrown and 100,000 persons perished, and at Christmas 1330.[2] Petrarch[3] describes a terrific tempest which he witnessed at Naples. This hurricane was felt over Italy and on the shores of the Mediterranean, but its violence was concentrated on that city, where the injury sustained by merchants was computed at 4000 ounces of gold—it was in Nov. 1343, on the night that Joanna granted to Petrarch the office of her chaplain and almoner, in imitation of Robert of Anjou, the Mæcenas of the 14th century. This tempest was associated with an earthquake. In England, a hurricane occurred in March 1389, which was followed by plague and famine. On the 5th of November 1430, the dykes of Holland were again ruptured by the storm-waves of the wind which we describe. The year before the memorable 1499, when the plague appeared in London, a terrific hurricane rolled among the Hartz Mountains, and laid in ruins the country watered by the Elbe. On the 3d of September 1658, a hurricane which raged in Europe, was felt in England:[4] the depression of the barometer on that occasion was probably the mediate cause of the death of Cromwell, which took place that day. In August 1675, the Barbadoes suffered from a devastating hurricane, which covered the island with the *debris* of the storm. Dampier, in 1681, witnessed at Antigua the effects of a similar tempest, which lasted with great violence for

[1] Physical Atlas.

[2] Hol. Chron. vol. i. book vi. p. 135; Ib. vol. iii. pp. 170, 243, 348, 473.

[3] Epist. de rebus famil. lib. v. 5.

[4] Mortimer.

several hours; water-casks were floated from the ships and carried quarter of a league inland; a ship was overturned, and another was drifted into a forest, while a third was stranded upon a rock ten feet above the highest tide. The dykes of Holland broke open on the 22d of November 1686 under the influence of a hurricane, and 10,000 persons perished.

On the 20th of May 1729, a remarkable hurricane visited England.[1] On the 11th of October 1737, hundreds of vessels and a fleet of Indiamen were severely injured, with great loss, and 30,000 individuals perished in Hindustan, by the same storm. In 1756, during a hurricane,[2] "the whole wood of Drumlanrig, in Dumfriesshire, was overset." About a century before, a forest in Ross-shire was overthrown by a violent storm; this gave rise to a peatmoss near Lochbroom, from which in less than fifty years the inhabitants dug peat.[3] This fact is worthy of particular attention, in connexion with the occurrence in mosses, of trunks of trees broken near their roots, lying all in the same direction;[4] where a sporadic tree is found immured, it may have fallen by age and decay, or been carried thither by aqueous transportation. On the 25th October 1768, the Havannah suffered by a hurricane.[5] In 1773, one visited the Mauritius and destroyed 300 houses in Port Louis; on the windward-side of the island the sea rose 45 feet. A disastrous tempest blew in Europe on the 11th November 1775. On the 10th of October 1780, a fearful hurricane desolated the Barbadoes;[6] it raged during two days and nights, destroying 4326 individuals and property worth £1,320,564 sterling. Twelve British ships, having an aggregate of 376 guns, were wrecked: one of these, the *Thunderer*, carried 74, and another, the *Stirling Castle*, 64. On the 12th April 1782, a calamitous hurricane blew in the Northern Atlantic, when the convoy and some of Admiral Rodney's trophies foundered—the Count de Grasse's ship, the *Ville de*

[1] Passage of Hur. from Sea at Bexhill, Sussex, to Newingden—Level—Chart; Ann. Phil. xii. 49.

[2] Dr Walker,—Lyell's Princip. of Geol. iii. 268. 6th ed.

[3] Dr Rennie's Essays on Peat, p. 65.

[4] Ib. p. 30.

[5] Ann. Register.

[6] Ed. Roy. Soc. Tr. vol. i.—Blane.

Paris of 110 guns, and several others of large size, were among the number. On the 22d of the same month, 7000 persons perished by a hurricane at Surat, in the East Indies. In May 1787, a hurricane blew in India from the N.E., when the ocean waves rolled inland to the distance of about twenty miles, on the coast of Coromandel; more than 10,000 of the inhabitants found a watery grave, and the carcasses of 100,000 cattle were strewed upon the marine mud.[1] Tradition reports a similar catastrophe about a century before.

410. In the present century, hurricanes of the most calamitous nature have not unfrequently occurred. On the 9th of November 1800, one raged in Europe. On the 22d of August 1806, one blew in the Gulf of Florida, on which occasion ten merchant vessels, homeward bound, under convoy of three ships of war, foundered.[2] A tremendous hurricane blew at Dominica and Martinique, on the 9th of September 1806. In March 1809, the famous storm termed the *Culloden hurricane,*[3] raged off the Cape of Good Hope, while a fleet of merchantmen under convoy of the *Culloden* and the *Terpsichore,* with four other ships of war, were making for Mauritius. Colonel Reid[4] has availed himself of this tempest to illustrate the circular theory of storms. A portion of the fleet ran in the hurricane for days; other vessels sailed into the vortex and foundered; some by lying to, soon got out of its danger; while others, crossing the calm in the centre of the circle, encountered a double storm blowing in opposite directions, although in fact it was the same tempest; there were other ships which altogether escaped the storm by cruising beyond the great whirl. This hurricane has been beautifully illustrated by a diagram in that valuable work, the Physical Atlas. On the 18th of October 1815, Jamaica was visited by a hurricane accompanied by two shocks of an earthquake; the thermometer remained at 75° during the visitation.[5] On the 28th of March 1817 and following day, a destructive hurricane was experienced in the Mauritius, and the rain

[1] Lyell's Princip. of Geol. iii. 286; Dodsley's Ann. Reg. 1788.

[2] Scoresby, Memor. of Sea, p. 382.

[3] Brewster,—Ed. Rev. vol. 68, p. 427.

[4] Law of Storms.

[5] Arnold, Ed. Phil. Jour. vol. vii. p. 257.

which fell was observed to possess a saline taste, acquired doubtless from the admixture of water from the ocean, carried by the wind.[1] In September 1819, a hurricane passed over Tortola, destroying property valued at £100,000. On the 9th of October same year, the district of Kutch,[2] on the west coast of India, suffered dreadfully from a hurricane and inundation; four months before, a terrific earthquake had laid waste the country.[3]

On the 24th of December 1821, there was a terrific storm at Genoa.[4] On the same night (24–25th) there was a severe thunder-storm in France, and enormous devastation in Appenzel, while similar calamities were experienced in the Rhinthal; in Italy the hurricane was accompanied by deluges of rain which produced destructive inundations.[5] This remarkable dispensation was attended by a great depression of the barometer, to which we have already referred.[6] A violent storm blew in England in November 1824, during which the sea made encroachments on the land.[7] This remarkable tempest wreaked its fury in Sweden and at St Petersburg, where much loss was sustained by the inundation which accompanied it, in addition to the disasters at sea. The barometer fell at Stockholm on the 13–14th of that month lower even than it did at the earthquake of Messina in 1783. On the 18–19th the hurricane was at its greatest violence, and its fury was unbounded. The destruction at St Petersburg in six hours was compared to that sustained by Moscow during the late war. The Neva rose sixteen feet above its level, whereas in 1777 its greatest height was only fourteen. The attending phenomena divided the opinion as to the cause of this extraordinary event; while some ascribed it to ordinary causes, others found an explanation in terrestrial convulsions.

[1] Edin. Encyc. vol. xiii. p. 386.
[2] Ed. Phil. Jour. vol. iii. p. 198.
[3] Ed. Phil. Jour. vol. iii. p. 120; Ib. vol. iv. p. 106; Lyell's Princip. of Geol. vol. ii. p. 306.
[4] Hailstone,—Cambr. Mem.; Edin. Phil. Jour. vol. vii. p. 183.
[5] Bibl. Univ. Jan. 1822.
[6] Page 31. See also Brandes,—Ann. of Philos. vol. xx. p. 263; Ib. vol. xxi. p. 311; Forchhammer,—Ib. vol. xix. p. 401.
[7] Lyell's Prin. of Geol. vol. ii. chap. vii.; De la Beche,—Geol. Man. p. 82; Ed. Jour. of Sc. vol. ii. p. 367.

Upon the 23d of that month, the barometer at Leith indicated a pressure of 28.45 inches, near the level of the sea.[1] A hurricane of great violence blew at Guadaloupe,[2] on the 25th of July 1825, when part of the governor's house was overthrown, heavy cannons were moved and dismounted, and a timber plank 39 inches long, nearly 9 inches wide, and 0.9 inch thick, was forced through a palm tree 17.7 inches in diameter. On the 5th of March 1828, one occurred in the Mauritius.[3] On the 24th of July 1829, a hurricane was experienced in this country near to Boston;[4] its breadth was estimated at a mile, and its length at eight; the loss sustained exceeded £70,000. On the 15th of September same year, a violent tempest of limited breadth, passed over Gorschoff, in Pskow, Russia; it was accompanied by hail, and devastated everything in its path, destroying several persons and cattle. In August 1830, two hurricanes visited the West Indies and eastern coast of America; the one has been traced through a distance of 3000 miles, and the other over 2500—the former advanced northwards at the rate of 500 miles *per diem*, enduring for twelve hours violently, at the different places over which it passed, and in a mitigated form for a much longer time.[5] A hurricane which occurred in August 1831,[6] transformed the Barbadoes into a desert, and killed 5000 individuals—the loss of property was computed at half a million. There were forebodings of a storm the night before, and a little after midnight it burst furiously from the N.E.: the wind veered to E., N., N.W., E., S.E., and S.W. At Dominica, St Vincent, Cuba, and Aux Cayes, the tempest did serious injuries; the rising of the sea at the latter place caused the death of 600 persons. At New Orleans the effects were severely felt, and at Natchez, 300 miles up the Mississippi, the court-house was overturned. This hurricane began in the Barbadoes on the 10th and reached New Orleans on the 16th, moving over a distance of 2300 miles, at the rate of 383 miles *per diem*.[7] In October same year, about 200 fine

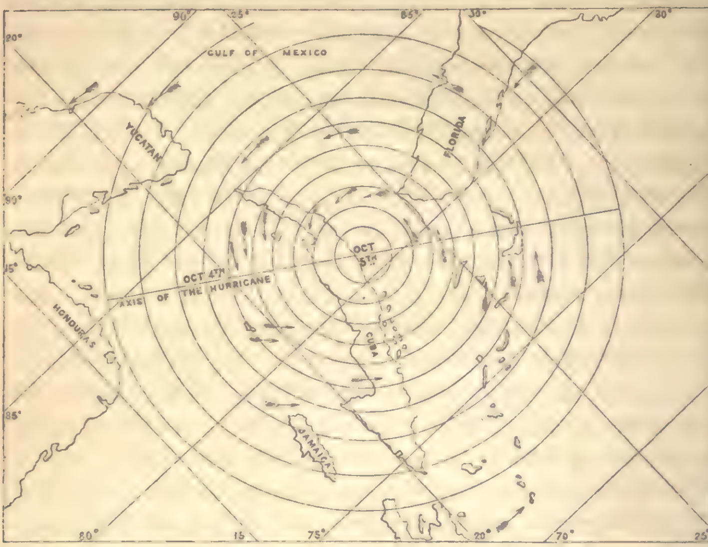
[1] Ed. Jour. of Sc. iii. 58. [2] Pouillet,—Elem. de Phys. &c. ii. 717, 718.
[3] Tyerm. and Ben. Op. cit. ii. 498. [4] Boston Gazette.
[5] Silliman's Amer. Jour. [6] See 108. [7] Silliman's Amer Jour.

trees were in a few minutes uprooted by a hurricane, at Thornden in Yorkshire. In India, towards the close of the same month, a hurricane blew over Balasore, between Calcutta and Madras, destroying thousands of the inhabitants, by the storm-waves and tempest. On the 21st December 1831, a terrific hurricane visited Raratonga, the chief of the Hervey Islands, in the Pacific Ocean, which has been described by the deeply-lamented missionary Williams.[1] In May 1832, a catastrophe similar to that of 1787, happened on the coast of Coromandel. On the 29th of November 1836, there blew in this country a terrific hurricane, and at Ostend scarcely a house was left unroofed.[2] This tempest began off the coast of Newfoundland on the 23d, in the parallel of St Lawrence; it reached Land's End on the 29th at 7.75 A.M.; Plymouth at 8.5; Poole at 10.5; London at 12.5 P.M.; Düsseldorf at 2; and Königsberg at 9 o'clock. It travelled in the axis of the storm, which passed between Dover and the coast of France, at the rate of fifty miles *per hour;* and the rotatory movement had a velocity of about 135 miles *per hour.* In London the barometer indicated 29.30 inches at 9 A.M.; and 28.82 at noon; by 2 o'clock the mercury had risen to 29.35. An awful hurricane ravaged the western coast of England on the 6–7th January 1839; many vessels were lost, and in the Mersey alone, at least 100 persons found a watery grave; in Liverpool twenty died by the falling of buildings. Dublin suffered severely; in Athlone, Limerick, and Galway, many houses were either thrown down or burned by the spreading of fires. Martins mentions having witnessed a hurricane during the 17–18th July 1841, at Grindelwald, in Berne, which began to blow between the Eiger and the Mettenberg, at the foot of the Schreckhorn, where the lower glacier issues. Before morning trees were broken and uprooted, houses unroofed and carried to a distance, while fragments of the ice were stranded in the Black Lutschine: this is the *foen* of the Swiss. In April 1843, a violent hurricane blew at Rodriguez, off Madagascar.[3]

[1] Miss. Enterpr. 8vo, pp. 385–393. [2] Physical Atlas.

[3] Thom's Inquiry into Nature and Cause of Storms in Indian Ocean, 8vo; Chart in Phys. Atlas.

411. In October 1844, there was a violent hurricane experienced in the Honduras Sea and the Atlantic Ocean, called by Redfield[1] the *Cuba Hurricane*. Coming from the Pacific



Hurricane at Cuba, Oct. 1844.

and Central America, it blew upon the Caribbean Sea on the 3d and 4th ; from the Honduras it passed over Cuba, Florida, the Bahamas, and pursued a north-easterly path to the island of Newfoundland ; the axis of the storm was in line N. 40° E. from the island of Ruatan on the Honduras coast, to an intersection of N. lat. 50° near W. long. 50° 40′. At the Havanna, seventy-two ships were found wrecked or sunk, houses were unroofed, and crops destroyed ; the loss was estimated at a million sterling. At Matanzas in Cuba, the barometer, which generally stood at 30 inches, fell to 28 on the 5th, and rose to 29.8 in. on the 6th at 9 A. M. Upon the 18–19th of the same month, a hurricane descended on Lake Erie, nearly destroying Buffalo, and visiting Montreal and Quebec. On the 21st of August 1845, two days after a violent whirlwind in France, a hurricane blew at Holmstadt in Norway ; the

[1] Silliman and Danas Jour. N. S. No. 3, p. 333.

sea was much disturbed in the same manner as it had been previous to the earthquake of Lisbon in 1775, and Messina in 1783. In August 1846, a hurricane visited Rugby, and continued for about three hours; upwards of a hundred trees were snapped across and uprooted, some measuring six feet in circumference: the line of the tempest extended about two miles, and the loss was estimated at two thousand pounds. On the 12–13th of September, Antigua and the neighbouring islands were visited by a similar storm; a few days thereafter, a terrific tempest swept over the Atlantic. On the 18th, a vessel foundered in N. lat. 37° and W. long. 50°. The succeeding day, the first impression of a hurricane was felt by the *Great Western*. At 3 A.M. of the 20th, the wind blew heavily; at noon, the larboard paddle-box was crushed by the fury of the wind, which, an hour before, had started from its iron fastenings the heavy ice-house and iron life-boat above. The tempest raged with unabated violence till midnight, when it lulled; again it roused itself, and continued till 8 A.M. of the 21st a fearful storm; at noon it ceased. At Newfoundland, a hurricane was experienced on the evening of the 19th, a few hours before it was felt by the *Great Western*. Early that day, the wind at that city was blowing strong from the N. E.; but it veered northward towards the afternoon, when it reached an awful height. The church of St Thomas is said to have been moved several inches from its foundation, houses fell, bridges were carried away, and several lives were lost. On the 8–12th October, a hurricane almost unexampled in fury, raged in the West Indian seas among the Caymans,[1] strewing them, the neighbouring islands, and Cuba with wreck and desolation. In this terrific tempest, the Rev. William Niven of Jamaica perished.[2] At Havannah,[3] the sky at sunset on the 10th indicated an approaching tempest; towards morning, the storm raged from the N.E., and continued with incredible fury till 10.5 A.M., when it lulled. Again it rose, veered to the N., than to W., and W.S.W., thus sweeping round nearly half of the windrose; about 4 o'clock it began

[1] Daily News, Dec. 21, 1846.
[2] Mission. Record. Feb. 1847, vol. ii. p. 19.
[3] Evening Mail, Nov. 6. 1846.

to moderate. The barometer at 1 A.M. of the 11th stood at 29.63 inches, and the thermometer was 77°.5 F. The mercury fell rapidly, till it sank to 27.7 inches at the height of the storm ; at 7.5 A.M. of the 12th, it rose to 29.95, and the thermometer was then 78°.5. The loss of shipping in the land-locked-bay of Havannah amounted to eighty-eight. Many persons perished, and much property was destroyed. The steam-ship *Tay* weathered this devastating hurricane, having sailed from Havannah for Vera Cruz on the 10th of October at 5 P.M. ; the wind then blew strong from the N.N.E., and continued till the 11th at 4 P.M. increasing in its fury ; at that hour it shifted suddenly to W. by N., and in a few minutes veered to S.W., then to E., and settled at W.N.W., blowing hardest at the north. The waves, which were of great magnitude, rose like pyramids breaking at the summits, sweeping the vessel with a sheet of drift.

On the 21st of the same month, a storm of fearful violence raged in the Irish Channel. On the 16th of March of the same year (1846), the islands of the Hervey group, in the Pacific Ocean, were again visited by a hurricane, still more terrible than that of 1831. Scarcely had the inhabitants recovered from the effects of famine and disease induced by that awful visitation, when this violent tempest swept their devoted islands. "Ten years' hard labour," says Mr Buzacott,[1] "will not restore us to the same state of temporal prosperity, we were in before ; but we dare not murmur ; our prayer is that those afflictions may be sanctified." Manjaia, another island of the same group, was on the 17th laid waste by the same tempest. So early as the 10th of February, the winds had been high, alternately raging with destructive violence and lulling into rest, but on that day its fury was irresistible. A violent hurricane blew in the eastern seas between Bombay and Sincapore, on the 17–19th April 1847 ; a large steam-ship was lost. On the 7th September same year, nearly 400 houses were destroyed by a similar tempest at St Petersburgh,—the rain fell incessantly for forty-eight hours. On

[1] Let. to For. Sec. Lond. M. Soc. ; Mission. Mag. and Chron. Oct. 1846, Mar. 1847 ; Ib. No. 134, July 1847, p. 113,—Gill.

the 18–19th August 1848, a tremendous storm blew off the east coast of Scotland; the loss of life amounted to ninety-three, and the value of the property destroyed was estimated at about £2000. Two days thereafter, Cheshire was visited by a hurricane from the S.W. which broke across many tall and handsome poplars, and uprooted others. At the same time, a very violent hurricane blew in the West Indies, sweeping over the islands of Antigua, St Kitts, St Thomas, and Nevis, but leaving untouched Barbuda on the north, and Monserat on the south. The hurricane subsided before 4 A.M. of the 22d.

412. A hurricane in the woods of New South Wales, is thus described by a lively writer.[1] "In the beginning of November 1839, I was journeying from Goulburn to Bathurst by the direct route of the Abercrombie River, through a wild country, covered almost entirely with forests of very lofty gum-trees. On my departure from Mr M'Allister's station in the morning, the wind was blowing strong, and the sky betokened tempestuous weather. As the day advanced, the gusts of wind became more and more violent, occasionally bringing down the branch of a tree. When I had arrived within three or four miles of the Abercrombie River, the air became suddenly warm, and a few flashes of vivid lightning accompanied by loud thunder denoted the approach of a storm. A strong instinctive sensation of fear came over me, such as I never before experienced; and in a short time, perhaps a minute, I heard a strange, loud, rushing noise; the air grew rapidly dark and thick, and my horse was evidently, like myself, under the influence of intense fear, and trembled violently. I exclaimed, although alone, 'This is a hurricane!' and jumped off my horse at the end of a fallen tree; the poor animal endeavoured to shelter himself by backing under a growing tree, which I prevented by a violent pull at his bridle, and then for the space of a minute or two saw nothing; the hurricane, for such it was, had reached me, and every thing was in total darkness. I fell on my knees, still holding my horse's bridle. The roaring crashing sound was

[1] Meredith, —New South Wales.

deafening, but it soon passed by, and the atmosphere again became clear enough to admit of my observing surrounding objects. My horse and myself stood alone in what a few seconds before had been a high and dense forest ; every tree was prostrate, either broken or uprooted, including the one from under which I had luckily pulled my horse, its ponderous trunk lying within a few feet of us. Fortunately the track of the hurricane was in the same direction as that in which the fallen tree lay at the end of which I dismounted, and thus the small space was left which saved us both. Immediately that the hurricane had swept by, the rain fell in torrents, exceeding any thing I ever witnessed in the tropics, and a heavy gale continued for two days."

413. *Great storm of* 1703. This was a hurricane ! Originating, probably, in the vast inland seas embasoned by the mountains and overhung by primeval forests, or over an unpeopled district of North America, it reached the eastern part of that continent, thence it swept the Atlantic Ocean, and increasing in fury, passed over Britain ; it crossed France, Holland, Germany, Sweden, the Baltic Sea, Russia, and a great part of Tartary, until it was lost in the Northern Ocean, returning probably to the spot whence it came, thus making a circuit of the globe. It raged with greatest violence on the 27th of November, *old style, i.e.* 8th December of our reckoning. The destruction was incalculable ; this country alone, suffered to the amount of more than four millions sterling ! In the royal navy, twelve ships were cast away, numbering above 1600 men and mounting 524 guns. The Bishop of Bath and Wells and his lady were among those who perished by the falling of dwellings, and in Sussex the sister of the Bishop of London had the same fate. The Eddystone Lighthouse was swept away, and in its ruins perished Winstanley the architect, who, confident of its strength, proudly said he only wished to be in it when it blew a storm ![1] So awful was this visitation, that by order of Queen Anne, a solemn fast and thanksgiving was publicly observed on the 19th of

[1] Belsham,—Hist. Gr. Britain ; Ph. Tr. 1704 : The Storm, by De Foe.

January 1704, and to this day, a sermon is annually preached in London in commemoration of the dispensation:

> "On the whirlwind's wing
> Riding sublime, Thou bidst the world adore,
> And humblest nature with thy northern blast."
>
> THOMSON.

414. An idea of the hurricane, and indeed of all those winds which move in circles, may be formed by causing water to revolve rapidly in a basin,—supposing the vortex to progress in a direct line, or axis, at about seven miles per hour. The water is calm in the very centre, but impetuously moved a little beyond, and violently agitated farther off. An electrical origin has been assigned to this impetuous tempest, whereby a rarefaction of the atmosphere takes place, and a rush of air from every side to restore the equilibrium, proportioned in intensity to the amount of the disturbance, and the celerity with which the change in density has been effected. It might thus be explained by the ascending current of Espy,[1] (406), caused, as he supposes, by the disengagement of *latent caloric* in consequence of a sudden aqueous precipitation: or, as others have ventured to suggest, by such a local change in the arrangement of the gases of our atmosphere, by the electric agency referred to, as would lead to the formation of a void, more or less perfect, according to circumstances. Sir John Herschel[2] suggests the possibility of tropical hurricanes arising from the premature diversion downwards of those aërial currents which blow towards the poles, above the trades, "before their relative velocity has been sufficiently reduced by friction on, and gradual mixing with, the lower strata." Plausible as the electric hypothesis may seem, we are disposed with Dove, to adopt the theory, that the hurricane proceeds from the circular course or eddy arising from the meeting of two opposing winds, and that it blows nearly at right angles to the radius of the circle in which it is moving. If we assume the theory of Espy, or that of a partial void, it is apparent that the atmospheric currents will be directed to the centre of the place of rarefaction,

[1] Philos. of Storms, 8vo, London 1841. [2] Astronomy, p. 132, note.

like the spokes of a wheel to its axis, an arrangement of the aërial pulses which we do not meet with either in the hurricane or tornado.

415. There is a wind which often blows over the American Continent, the impetuosity of which ranks it with the hurricane and tornado, but it is unlike these tempests in this respect, that neither thunder nor lightnings attend, nor does rain follow in its wake. It is called the *wind-storm*, and is thus described by Dr Reed, who witnessed it at Washington :—"Quietly the soft and refreshing breezes went down ; a haze came over the sun, so that it shone as behind a gauze curtain. Every noise was stilled, except that of the frog, which was unpleasantly audible. The sky got silently darker and darker; the atmosphere became oppressive; and not a breath of air was felt. Suddenly in the distance you would see things in commotion ; and while everything was yet quiet about you, you might hear the distant roarings of the wind. Then the cattle ran away to their best shelter ; then the mother calls on her heedless children ; and the housewife flies from storey to storey to close her windows and shutters against the entrance of the coming foe. Now the dust, taken up in whirlwinds, would come flying along the roads ; and then would come the gust of wind, which would make every thing tremble and set the doors, windows, and trees flying, creaking, and crashing around you. You would expect the torrent to fall and to roll ; but no, there was neither rain nor thunder. It was wind, and wind alone ; and it wanted nothing to increase its power on the imagination. It raged for a few minutes, and then passed as suddenly away, leaving earth and sky as tranquil and as fair as it found them."

416. The *Squall* is a violent gust suddenly arising and quickly passing, often met with in confined seas, where islets and rocks interrupt and reverberate the wind. Rapid alterations in temperature may in most cases be found to be the cause. In the Mediterranean and the Archipelago, it is frequently met with and dreaded. In the Chinese Seas, a wind called the *white squall* occurs ; and so local is this current, that the topmasts of vessels will be suddenly carried away while

the ocean is unruffled by the wind. From this circumstance considerable danger attends the navigation of those seas.

417. Bize, Bora, Mistral, Tramontana, or Snow winds. The *Bize* is a cold piercing wind of Languedoc, which blows from the snowy tops of the Pyrenees and the chilly summits of the Jura-ridge. The *Tramontana* is a similar wind coming from the Apennines, denominated in other countries *the snow-wind.* The intensity of the cold of these winds arises from the dryness of the air which passes the snow-clad mountain, the temperature of which is farther reduced by the evaporation induced by it in its passage,—for snow melts less rapidly when the air is dry than when it is moist, and during evaporation, about seven times more heat is absorbed than in the process of liquefaction, consequently the wind which causes evaporation but does not melt, is much colder than that which liquefies. The Spaniards call the cold piercing N. and N.W. wind from Galicia, the *Gallego.* The *Mistral* is a Mediterranean wind, more steady than the bize; it blows violently while it continues, and is felt particularly at Avignon, Marseilles, Montpelier, and other places in the south-east of France, where it is styled one of the "fléaux de la Provence." It is the true north west wind of the Gulf of Lyons,—a sea which, from its physical position, is much exposed to heavy winds and severe thunder-storms. The *Bora* blows down the Adriatic in the direction of the Julian Alps, and is much dreaded, —the aspect of the sky warns the seaman of its approach.

418. The Tourmente, Guxen, or Snow-storm of the Alps. These winds are the dread of the chamois-hunter traversing the Alps: in an instant the gust envelops the mountain and the traveller in snow, so thick as to obliterate every trace of the road and conceal the landmarks; the snow may be falling, or borne on the wind from the mountain. To advance is to plunge headlong into some abyss—to remain is to run the risk of being buried in the drift; dangers beset on every side, and yearly, lives are sacrificed by those, who, without a guide or perfect knowledge of the spot, are overtaken in the pass. The hardy moutaineer accustomed to the *tourmentes,* can generally foresee their approach by the appearance of the sky,

and provide against the danger. The Spaniards designate the violent and perilous snow-storms of the Andes, *temporales*, from their short duration.

419. *Variable or erratic winds of temperate regions.* Excepting the winds which blow about the equinoxes, and termed Equinoxial gales, the winds of extra-tropical regions are variable, blowing at no stated period, and from no fixed direction. From the records of the Royal Society we find that in Britain, the prevailing winds in the course of a year are as follows :—S.W. blows during 112 days ; N.E. = 58 ; W. = 53 ; N.W. = 50 ; S.E. = 32 ; E. = 26 ; S. = 18 ; and N. = 16 days. In Scotland, according to Dr Meek,[1] during seven years' observation, the average is as follows :—S.W. = 174 days ; N.E. = 104 ; S.E. = 47 ; and N.W = 40 days. In Ireland the prevailing winds are the W. and S.W. We thus find that the most constant winds in Great Britain are the S.W. and N.E., and the same holds true over Europe,—Russia excepted,—and in America. As we advance into the European Continent, Schouw[2] observes that the increased ratio of westerly over easterly winds diminishes. Although these winds appear to be the effect of capricious causes, we cannot but think that they follow laws not yet fully developed. From April to May the northerly and easterly winds are frequent, arising from the current which flows southwards to replace the heated air over the Atlantic ocean, warmed by the solar rays as that luminary approaches to the summer solstice. In summer and autumn the opposite winds prevail, and the atmosphere is more moist and warm, because the balance of temperatures being now in favour of the land, the winds blow from the ocean. As the year advances, the winds first noticed again predominate, but they are accompanied by greater humidity than in the spring. It has already been observed, that the trade-winds give rise to an ascending current near the equator, and determine a westerly wind in the higher regions of the atmosphere, which descends about N. lat. 30°, (vide 380), and causes the predominance of S.W.

[1] Stat. Acc. of Scot. vol. v.

[2] Beiträge zur vergleichenden Klimatologie.

winds. By the excess of these S.W. and N.E. winds, Professor Dove explains the production of the other variable winds of temperate regions. If we notice opposing currents upon a sheet of water, we will observe at the meeting of these currents, at one time a circular motion, at another perfect quiescence. Dove considers that whirlwinds of variable diameters and intensity arise in the region between those winds which are steadily blowing, and give rise to the phenomena in question,—when the diameter is small, we shall have the whirlwind properly so called, when larger, the tornado, or the hurricane, or the winds of temperate regions, in proportion as the circle is increased in radius.

420. Professor Forbes of Edinburgh, in his Report on Meteorology to the British Association in 1840, states what Dove has observed, that when the wind changes it *generally* does so from the right to the left of the windrose, or in the direction of the handles of a watch. In the southern hemisphere there is an exception to this law ; hence on the west of the windrose the warm wind is followed by a colder, the reverse of what is observed upon the eastern side of the card.

421. The *law of storms*, or the circular and parabolic direction which they generally follow, has been ably investigated by Reid, Redfield, Espy, Capper, Dove, and others, and determined beyond the shadow of doubt.[1] We have already several times referred to it. In its practical bearing it is of the greatest importance. The usual course of the wind in its veerings has been already noticed, viz.—from the E. to W. by S. in the northern hemisphere ; and from E. to W. by N. to the south of the equator ; but there are exceptions to this rule. However, when a vessel is met by a tempest blowing from the S.E. changing to S. and W., she should be steered to the S.E., which is the region S.E. of the violent storm ; on the contrary, when the wind blows strong from the N.E.

[1] See Redfield and Reid on Storms in Jameson's Jour. vol. xx. xxv.; Capper on prevailing storms of Atlantic Coast of N. America, in the same Journal, vol. xviii. ; Silliman's Jour. ; Espy,—Philos. of Storms ; Dove,—Pog. Annalen, 1841, tom. lii ; Athen. No. 565.—Reid ; Ib. No. 676,—Epsy ; Thom,—Inquiry into Nature and Cause of Storms in Indian Ocean ; Piddington,—Horn-book of Storms, Calcutta 1844, &c.

veering to N. and N.W., she should be directed N.W.,—these indications being good in the temperate zone of the northern hemisphere. Again, if in the same hemisphere, and within the torrid zone, the wind blows from N.E., E., and S.E. the vessel must be guided to the N.E. ; but if it blows from the N.W. veering by W. to S.W., then she should steer S.W. In the southern hemisphere the following are the indications :—if within the tropics, the wind blows violently from S.E., turning to S. and S.W., steer N.W. ; but if it blows from E. to N., and N.W., steer S.E. In the southern temperate zone, if the wind is N.E., then N., and N.W., sail N.E. ; if S.E., S., and S.W., the vessel must be steered S.W.,—the object in all these movements being to sail out of the storm.

422. Temperature of variable winds. Although the erratic winds of extra-tropical climates have their temperatures modified by physical circumstances, leading to anomalies and local differences, still the results of meteorological observations exhibit some very interesting constances. The coldest of all winds, with scarcely an exception, is the N.N.E., while that one diametrically opposite is the warmest. The mean temperatures of the eight leading winds, according to M. Otto Eisenlohr, are as follows :—

	At London.	At Paris.	At Carlsruhe.	At Moscow.
N.	= 45°.77′ F.	= 53°.65′ F.	= 49°.8′ F.	= 34°.2′ F.
S.	= 52.43	= 59.78	= 54.7	= 42.73
N.E.	= 46.54	= 53.16	= 46.9	= 34.6
S.W.	= 51.55	= 58.88	= 51.8	= 42.24
E.	= 49.33	= 56.9	= 47.32	= 38.35
W.	= 50.43	= 56.55	= 54.	= 41.7
S.E.	= 51.04	= 59.45	= 54.	= 40.33
N.W.	= 47.68	= 54.3	= 52.7	= 34.5

423. Of the effects of variable winds upon health it is not the design of the present volume to treat, but who has not experienced the inconvenience arising from easterly blasts? The whole creation suffers from its malign influence. We need not ask the gouty or rheumatic of their agonies, the neuralgic of their pangs, nor the hypochondriac of their suf-

ferings; to the consumptive it blows destructively. How different are our feelings under the genial breath of the opposite wind, and its neighbours on the western side of the windrose. The south may bring moisture, and the north whiten the ground, but though the latter is cold, it is bracing, and neither, is absolutely disagreeable. The east wind and its companions are the unwelcome visitors,—and why is it so?

CHAPTER XVIII.

Πάσας τὰς ἡμέρας τῆς γῆς, σπέρμα καὶ θερισμὸς, ψύχος καὶ καῦμα, θέροςκαὶ ἔαρ, ἡμέραν καὶ νύκτα οὐ καταπαύσουσι.—ΓΕΝ. ή. 22.

"The seasons are regular enough to authorise expectation, while their irregularity induces, on the part of the cultivator of the soil, a necessity for activity, vigilance, and precaution."

424. It was a favourite opinion with the ancients, that events followed in sequential series—hence arose the platonic year, or *annus magnus.* This was a period of 25,868 years,[1] during which the equinoxes complete the series of retrogressions, in other words, when the equatorial and ecliptic axes of the earth being ideally prolonged, the pole of the former shall have revolved round the other. Then, the world, in their opi-

[1] **This period has been variously estimated. We give the cycle as determined by Sir John Herschel,—Astron. p. 169. Tycho Brahe assigned the length at 25,816 years; Cassini, at 24,800; and Ricciolus, at 25,910. The ancients extended the period far beyond six-and-twenty thousand years, even to that of 300,000. Cassander lengthened it to 360,000 years; and according to Orpheus, it was 120,000 years. See Prichard,—Egypt. Mythol. p. 182; Censorinus,—De Die Natali, &c.**

nion, renews the series of phenomena, and things return in the exact order as before. Without assenting to such an ideal and wild hypothesis, we would observe, that in a long circle of years there may exist a meteorological uniformity as yet unobserved, though the individual seasons may present much uncertainty in character.

425. In this variable climate it is not easy to presage alternations in the weather, but experience has established a connexion between certain signs and succeeding changes. In the serene skies of eastern climes, one whose attention has been led to the contemplation of atmospheric phenomena, often prognosticates with unerring certainty. That the Jews were apt in these observations, we learn from the words of Christ as given by St Matthew and St Luke.[1] A cloud rising from the Mediterranean is a sure token of rain.[2] "The approach of rain," says Dr Walsh,[3] "is always indicated here, as it was in Syria, by the appearance of a small, dark, dense, circumscribed cloud, overhanging the Euxine or the Propontis. A dervish stands on the top of the Giant's Mountain, and when he sees the cloud, he announces its approach. I one day climbed to the same place and saw the dervish on the watch. The cloud rose out of the sea and the rain immediately followed." The same traveller writes,—"Mustapha had early in the morning asserted that the weather would change, and when I asked him, why? he said, he knew from the red and lowering aspect of the sky."

426. In this country, the following prognostications have been observed :—

From the Barometer. The absolute height of the mercury in the tube of this instrument, measures the weight of the atmosphere at the period of observation ; changes in its height indicate alterations in atmospheric density, and consequently in the weather,—present rather than prospective. Any sudden change indicates an approaching variation of the weather, though one of short continuance ; a gradual change indicates

[1] Matt. ch. xvi. v. 3; Luke ch. xii. v. 54, 55; 1 Kings xviii. 44; Vide Homer,—Il. iv. 275.

[2] Lander,—Trav.; Shaw,—Trav. ii. 127.

[3] Constantinople, Resid. in, during Gr. and Tr. Revol.

the same, but of longer duration. A rapid depression may be speedily followed by a tempest, whose fury will be spent at the place of observation or at the distance of many miles. This observation is worthy of particular attention at sea, as it may be the *only visible sign* of an impending storm. The following narrative powerfully illustrates the fact. It is mentioned by Dr Neil Arnott,[1] who states that he was "one of a numerous crew who probably owed their preservation to its almost miraculous warning. It was in a southern latitude. The sun had just set with placid appearance, closing a beautiful afternoon, and the usual mirth of the evening watch was proceeding when the captain ordered to prepare with all haste for a storm. The barometer had begun to fall with appalling rapidity. As yet the oldest sailors had not perceived even a threatening in the sky, and were surprised at the extent and hurry of the preparations; but the required measures were not completed when a more awful hurricane burst upon them than the most experienced had ever braved. In that awful night, but for the little tube of mercury which had given the warning, neither the strength of the noble ship, nor the skill and energies of the commander could have saved one man to tell the tale." A writer in the United Service Journal mentions another good illustration.[2] It was in October 1820, about 3 P.M., when the lieutenant of the watch, on board a British ship of war, off Marseilles, inquired if he might be allowed to set additional sail, as a slight breeze was springing up. Every thing seemed to lull apprehension, but there was an unnatural clearness in the atmosphere, and the mercury had suddenly sunk 0.3 of an inch, and had its surface concave. "No," replied the superior officer, "turn the hands up, shorten sail, and we'll get the top-gallant masts on deck." Although there were as yet no other signs of a gale, scarcely had the operation of reefing been concluded, before it blew a violent storm which continued till the morning. The terrific gale of the 6–7th December 1847, which blew on

[1] Elem. of Phys. vol. i. p. 350; see Stevenson.—Ed. Phil. Jour. vol. ii. p. 196,—*Sympiesometer*.

[2] Unit. Ser. Jour. 1829, part ii. p. 25.

both sides of the island with great loss, was attended by a remarkable fall of the barometer. The author was at sea, on passage from Liverpool to Glasgow, when he observed the mercury so low as 28.2 inches; he cannot say that this was the lowest indication, for so violent was the storm that he was unable to continue observations. As the fall of the barometer is observed to be generally accompanied by a rise of the thermometer, both instruments should be consulted. During a recent equinoxial gale, the writer had an opportunity of noticing this fact. The preceding day was cold and calm; during the night the wind rose from the S.W. with much rain and a high temperature; the wind increased in impetuosity, so as to tear branches from the trees, and the barometer fell suddenly from 30.0 to 29.5 inches, but the thermometer rose several degrees above that of the previous day. The rising of the mercury generally indicates fair, as its descent foretels rainy, weather. Rapid fluctuations indicate unsettled weather. If the barometer is high in winter, frost may be expected; and if during frost it rises, snow will follow; if it falls, there will be a thaw. If it falls rapidly in hot weather, thunder is foreboded. In this country it rises with an east and falls with a west wind. It oscillates most in variable winds, and about the equinoxes. It is more stationary in summer than in winter, and has periodical daily tides. The higher the mercury, the higher the temperature generally, for the density of the air being increased, it parts with a greater amount of latent heat. If the sky is cloudy with a low barometer, showers will fall; if overcast and the mercury high, it will not rain. Anomalous descents, not attended or followed by corresponding atmospheric mutations, result generally from distant contemporaneous storms. In the oscillations of this instrument regard must always be paid to the direction, temperature, and humidity of the prevailing wind.

427. *From the Sun*—

"Sol quoque, et exoriens, et quum se condet in undas,
Signa dabit: Solem certissima signa sequuntur,
Et quæ mane refert, et quæ surgentibus astris.
Ille ubi nascentem maculis variaverit ortum,
Conditus in nubem, medioque refugerit orbe,
Suspecti tibi sint imbres." *Georg.* lib. i. v. 438 *et seq.*

"Above the rest the sun, who never lies,
Foretels the change of weather in the skies,
For if he rise unwilling to his race,
Clouds on his brow and spots upon his face;
Or if thro' mists he shoots his sullen beams,
Frugal of light, in loose and straggling streams,
Suspect a drizzling day."

DRYDEN.

If the sun is setting in a thick cloud and the eastern horizon red; or rising red with blackish beams, dim, or in a muddy cloud "shorn of his beams,"—rain is prognosticated: if his disc is contorted, a storm is not far off. If rising or setting pale with dark beams or red streaks; or if setting red with an iris; or setting in so white a light that his disc can scarcely be defined; or rising with a red northern sky,—wind is foretold. If setting clear in a red sky; or rising clear surrounded with an iris which gradually disappears as he ascends, the clouds at the same time making for the west,—fair weather is indicated.

The evening red, the morning grey,
Is the sure sign of a fine day.

How beautiful is the poet's description of the early blush of such a day,—

"But yonder comes the powerful king of day,
Rejoicing in the East. The lessening cloud,
The kindling azure, and the mountain's brow
Tipt with etherial gold, his near approach
Betoken glad." THOMSON,—*Summer*, v. 81.

"Solem quis dicere falsum
Audeat."

428. *From the Moon.* If pale and the cusps blunt, rain is indicated: if the cusps are blunt two or three days after new-moon, rain is foreboded for that quarter. If the moon is not visible for three or four days after change, and the wind is blowing south, rain for some time is foretold. If the wind is south, and an iris surrounds its disc, probably the next day will be wet. If distorted, broken, or if mock-moons are seen, a tempest is near. A lunar halo indicates unsettled weather;

shepherds remark that if the halo is not equally distinct throughout, the storm generally comes from the point to which this indistinct part of the meteor is directed. If the disc is much enlarged, or of an unnaturally red colour, or the cusps sharp and blackish, wind is foretold: if clear, bright, and the spots seen distinctly, fair weather is indicated. If the cusps are sharp upon the 4th day after new-moon, it will be fair till full. Observations from the phases, as given in almanacs, are worse than useless. Toäldo's tables are not valuable,—his descriptions are problematical. The same may be said of the tables of Cotte. Flaugergues[1] has pursued the inquiry.

429. *From the Stars.* If clear and numerous, twinkling brightly, fair weather in summer, and frost in winter is prognosticated. If large and dull, or the scintillation imperceptible, rain is approaching. When seen in motion wind is foretold.

430. *From Twilight.* When the sun has gone down, and the western sky presents a purple hue, with a haziness in the horizon, the following day will be fine; but should the predominating colour be pale yellow, extending high towards the zenith, there will be a change of weather. If at sunset the eastern sky is very red or purple, or has a copper hue and lustre, rain may be expected. If the twilight is unusually protracted, though the atmosphere seems very clear, the higher regions are charged with moisture, and soon it will be precipitated. The author observed several very luminous twilights in the summer of 1848, which were followed by protracted rains.

431. *From the Looming.* When very distant hills start into distinct view, with a clear outline and transparent atmosphere, rain will soon descend, for the air is highly charged with invisible watery vesicles.

432. *From the Rainbow.* If the predominating hue is green, it denotes continued rain; if red, rain and wind.

A rainbow in the morning is the shepherd's warning:
A rainbow at night is the shepherd's delight.

[1] Bib. Univ. xl. 283.

433. *From the Clouds.* These afford the best indications. If flying here and there, appearing red in the early part of day, or of a leaden hue in the N.W., then wind is indicated. If at sunset they begin to disappear, and have their edges tinged with yellow, the weather is fair and settled. If yellowish, and with a high wind they are moving heavily and soon darken the sky, hail in summer, snow in winter, is foretold. In describing the varieties of clouds several indications were mentioned. The *wind-gale*, or prismatic colouring of the clouds, is accounted by seamen a bad prognostic.

434. *From Mists.* If seen rising towards evening from a stream or meadow, heat next day is indicated,—but should they continue to arise, rain will follow. If the mist appears before sunrise about full moon, fair weather for several days may be expected: mists gathering around the mountain-top indicate approaching rain. Mists in autumn are often succeeded by wet weather; those of spring are seldom followed by rain.

435. *From the Wind.* If it whistles or howls, or veers much about, rain will follow,—if it rains before sunrise, it may go off before afternoon, but if it comes on after the sun has risen, it is likely to continue. A heavy shower after a high wind has begun to blow, indicates an approaching calm.

In connexion with the prognostications from winds, we would give a summary of the effects produced by variable winds upon the pressure, temperature, elastic tension, and humidity of our atmosphere, as observed by Kämtz and Dove.[1] The *barometer* falls under E., S.E., and S. winds—changes to ascent with S.W.—rises with W., N.W., and N. winds—and begins to descend with those which are N.E. The *thermometer* rises under E., S.E., and S.,—begins to fall under S.W., —falls with W., N.W., and N.,—and changes to ascent with N.E. winds. The *elasticity of aqueous vapour* increases with E., S.E., and S.,—changes to decrease with S.W.,—decreases with W., N.E., and N.,—and changes to increase by N.E. winds. *Humidity* decreases relatively from the W., passing by N. to E.,—and increases, on the contrary, from E., by S. to W.

[1] Athen. No. 685.

436. The *Vegetable kingdom* affords many valuable indications, dependent probably upon the electric tension of the air increasing the susceptibility of the plant. In the British Flora the following plants contract the corolla on the approach of rain :—*Anagallis arvensis,*—scarlet pimpernel; *Convolvulus arvensis, sepium,*—bindweed; *Arenaria rubra,*—red sandwort; *Veronica chamœdrys,*—speedwell; *Stellaria media,*—stitchwort; *Tragopogon pratensis,*—goat's-beard, often called "go-to-bed-at-noon," from its closing its petals at mid-day; *Exacum,* or gentianella.

437. *From the Animal kingdom.* If birds of passage appear or disappear unusually late or early, the coming seasons will be mild or rigorous accordingly. *A storm* is foretold when sea-fowls make for land and fishes seek deep water: the *weet weet* of the petrel is heard, and the bird skims the waves. *Rain* is indicated by land-birds becoming noisy, restless, or seeking their roosts—flocks of rooks and crows suddenly disappearing—single magpies gathering food—swallows flying low—untimely cock-crowing and clapping of wings—the early note of several small birds. It is foreboded when moles are active—cats wash their faces—dogs scrape the earth—asses bray—oxen snuff the air—domestic animals restless and violently gamboling—by rats and mice becoming unusually active—spiders disappearing or falling from their webs—earthworms coming to the surface—bees hastening home—ants keeping their nests—flies dull—frogs and toads croaking and approaching houses—the leech creeping to the top of the water bottle. *Fair weather* is indicated by sea-birds leaving land—kites and swallows making lofty flights—the song of birds loud, clear, and joyful—bats appearing early in the evening—gnats playing in the sunbeam—spiders active—glow-worms shining upon the banks—the leech reposing motionless at the bottom of the water. *Wind* is indicated by the wild geese gathering in flocks and flying high—water-fowls sporting at the water-side, especially in the morning—rooks unusually active—the king-fisher making for land—the leech restless. The extreme sensibility of birds to hygrometric changes has been ascribed to the expansion and contraction of their quills

under the influence of moisture. It will be remembered that Chiminello constructed a hygrometer, many years ago, with the barrel of a quill. The *actinias* or sea-anemones, have sometimes been termed animal barometers, from their susceptibility of atmospheric impressions.[1]

438. The following anecdote, which not only illustrates the prognosticating powers of the spider, but is fraught with a moral lesson, will be excused. That despised creature once encouraged the heart of a Scottish monarch—Robert the Bruce,—and urged him on to victory;[2] at another time it preserved an army from retreat, if not from utter ruin.[3] Quatremer Disjonval, seeking to beguile the tedium of confinement within the prison-walls of Utrecht, had studied attentively the habits of the spider, and eight years' observation had rendered him an adept. It was in December 1794, that the French army was encamped in Holland. They were advancing on the ice "almost in a state of nudity, marching in shoes whereof the upper leather was all that remained,"[4] and victory seemed declared for the Eagle of the Republic, if the frost which was of unprecedented severity continued. The Dutch envoys had failed to negotiate a truce with Pichegru. Unexpectedly it thawed—the Dutch were about to triumph, and the French generals were seriously meditating the withdrawal of the troops, which seemed the only hope of their returning home in safety. Disjonval looked forward to the issue with hopes and fears—he sighed for freedom; but his prospects seemed for a moment blasted. The spider forewarned him that the change was to be of short duration, and he knew by past experience that it did not deceive. He hastened to communicate with the army of his country, and with difficulty was successful. He pledged himself that before a fortnight's sun had set, the waters would be again hardened, and sufficient time would be given for the completion of the war. Pichegru listened and believed. Within twelve days the frost returned; on the 16th of January 1795

[1] Dicquemare in Johnston's Brit. Zoophytes, p. 225.

[2] Hist. of Scotl.—Scott, vol. i. p. 64.

[3] For. Quart. Rev., Jan. 1844.

[4] Thiers,—Hist. Fr. Revol., Redhead's Transla., 8vo, p. 477.

the cavalry entered Amsterdam, and on the 28th, the prison-doors of Utrecht were opened to the adjutant. Thus did a tiny spider seal the destiny of Holland!

439. *From Inanimate bodies.* *Rain* is indicated by music-strings breaking, canvass relaxing, wood swelling, soot tumbling down the chimney, pools seeming muddy, bells heard at a great distance—providing the weather is not frosty, or the sound collected in the focus of a sail,[1]—and by various saline minerals moistening. In the Polish mines of Viclizka, near Cracow, a large block of rock-salt, called Lot's Wife, indicates to the miners the hygrometric condition of the atmosphere above. Probably it is to the presence of the same mineral, that a stone in the north of Finland owes its hygrometric qualities. When the weather is fair, this stone appears covered with white specks, but when rain approaches, these disappearing, it assumes a dark-grey colour. *Wind* is indicated by an agitation of leaves more than usually great, flame flickering, and the sea calm with a murmuring noise. A long-continued swell announces a gale,—

> "For ere the rising winds begin to roar,
> The working seas advance to wash the shore."
>
> DRYDEN'S *Virgil.*

A *thaw* is indicated when snow descends in large flakes with a southerly wind, and when the general indications of rain are presented; *thunder*, when the atmosphere is sultry and the ground much cracked.

440. The classical reader need not be reminded of the verses of Virgil[2] or Thomson.[3] From the prognostications given, changes may be generally foretold a few hours previous to the mutation; but to determine a year, or even a month, or a week in advance, is impossible. "Never," says Arago, "whatever may be the progress of the sciences, will the *savant* who is conscientious and careful of his reputation, speculate on a prediction of the weather." Once more

[1] See Arnott,—Elem. of Physics.

[2] Georg. i. 355, *et seq*; Varro.

[3] Seasons,—Winter, v. 118—155.

to quote the eloquent words of a veteran in the pursuit of science, and in the discovery of its truths,—Sir David Brewster;[1]—"In the very atmosphere in which he lives and breathes, and the phenomena of which he daily sees and feels, and describes and measures, the philosopher stands in acknowledged ignorance of the laws which govern it. He has ascertained, indeed, its extent, its weight, and its composition; but though he has mastered the law of heat and moisture, and studied the electric agencies which influence its condition, he cannot predict or even approximate to a prediction, whether, on the morrow, the sun shall shine, or the rain fall, or the wind blow, or the lightnings descend. 'The wind bloweth where it listeth, and thou hearest the sound thereof, but canst not tell whence it cometh, and whither it goeth.'"

In drawing to a close this feeble attempt to raise upon a multitude of facts, a science connected by generalities, the author would observe that there is yet much to be done. The Meteorology of the present epoch is very different from that of Aristotle and his pupil Theophrastus, or even that of the early years of the present century. The unwearied labours of a goodly host distributed over the globe, watching every cosmical phenomenon, and recording at stated times their observations, have been already amply rewarded; and we look forward with no small expectation to "coming events," which, in the discoveries of Faraday, may be said to have "cast their shadows before." The various meteors described are not the offspring of separate causations, but functions of common principles. The intimate connexion and agency of heat and electricity is apparent in the *tout ensemble* of the science. The former is the *primum mobile* of Meteorology, and oxygen, nitrogen and hydrogen, the elements with which it operates, —excluding from this category "falling stones" and "shoot-

[1] Nor. Brit. Rev. No. x. vol. v. p. 454.

ing stars," which, for reasons given, we do not consider of atmospheric origin.

> "These are Thy glorious works, Parent of good,
> Almighty, Thine this universal frame,
> Thus wond'rous fair; Thyself how wond'rous then!
> Unspeakable, who sit'st above these heav'ns
> To us invisible or dimly seen
> In these Thy lowest works."

APPENDIX.

METEOROLOGICAL INSTRUMENTS.

"Almost every one of these instruments, to which several more might be added, has brought in sight a new country, and has enriched science not only with new facts, but with new principles."

Third Dissertation, Encyc. Britan.

441. The length to which this treatise has unexpectedly extended, precludes a full description of all the instruments used in Meteorology. We shall notice, however, those which are most simple and important, observing, that in the furnishing of a meteorological observatory, the apparatus is often complex and expensive.

The *Barometer*—(βάρος heavy, and μέτρον a measure). The Aristotelian tenet,—the *fuga vacui* of the schoolmen,—the horror of nature to a vacuum, was the false philosophy of the days of Galileo. That gifted man had gone far to shew the true principles of suction. He had ascertained that air is ponderable, and he calculated its weight; he had even obtained a vacuum different from that of any other, by applying weights to the piston-rod of an inverted syringe—but he went

no farther.[1] The infirmities of old age, increased by the persecution to which he had been subjected, were creeping upon him, and he consigned to his young friend Torricelli, those laurels which would have added to the lustre of a name even then honoured with human immortality. Substituting mercury for water in some of his experiments, Torricelli found that the "horror of the vacuum" did not in that case exceed thirty inches, whereas it amounted to thirty-two feet when water was employed. Hence he justly concluded, that both the water and the mercury exerted the same pressure, and that the counter-balance was of course equal.[2] This was a grand advance in the pursuit of truth—it was an epoch in the annals of philosophy,—but the Florentine Professor wished to breathe freely under the burden of the discovery, before such a tribunal as the Inquisition, and, communicating the fact to Viviani, who repeated the experiment in 1643, he withheld his discovery till 1645. Death, shortly after, closed the eyes of this promising mathematician, yet in the bloom of manhood—Torricelli was gone; but Clermont had given birth to Blaise Pascal, in whom the loss was supplied. In 1646, Pascal, renowned for piety as he was for the learning of the schools, repeated at Rouen, in presence of a large assembly, the Torricellian experiment. Revolving in his inventive mind a plan which would directly prove the correctness of his opinion, the youthful philosopher resolved to institute the comparative test of altitude upon the mercury. This was an *experimentum crucis*, perhaps the earliest recorded in scientific annals. The mind rested between the *fuga vacui* of the schoolmen, and the ponderability of the atmosphere—it was an *instantia crucis* in the language of the Baconian philosophy, requiring a fact explicable by the one hypothesis, but not by the other. The letter, dated November 15. 1647, in which Pascal promulgates his views, is still extant. Descartes,[3] in Sweden, seems to have anticipated the French philosopher in this thought, nevertheless, the conception of the Puy-de-Dôme experiments was *original* in the mind of Pascal.

[1] Galileo—Dial. [2] See Montucla's Hist. Mathemat. ii. 203.
[3] Descartes,—Princip. Ep. 67, 1644; Letter to Carcavi, June 11. 1649.

442. Illness prevented Pascal from visiting Auvergne, where he hoped to arm himself with facts for establishing his views, which were already opposed by the Romish dignitaries. In his relative Perier, however, he found a suitable substitute, and on the morning of Saturday, the 19th of September 1648, at eight o'clock, he, in company with the chief men of Clermont, prepared for the experiment. In the garden of the Pères Minimes, in the lowest part of Clermont, the mercury in the tubes stood at the same altitude, viz. 26 inches 3.75 lines, *i.e.* 28 English inches. On removing one of them to the summit of the Puy-de-Dôme, elevated 529 toises, the mercury was observed to stand at 23 inches 2 lines, *i.e.* 24.7 English in.—no less than 3 inches and 1.75 Fr. lines lower than it did in the garden. The experiment was made at an intermediate station, elevated about 150 toises—La fond de l'Arbre—and there, the mercury stood at 25 inches. On returning to the Minimes, the indications were the same as in the morning.[1] What could be more decisive? These experiments were repeated in other places, and always with similar results. Thus, at the top and base of Nôtre Dame, St Jacques, De la Boucherie, and elsewhere in France; in England in 1653;[2] and in Scotland in 1661, by Professor Sinclair,[3]—who found the difference on the top of Tinto in Lanarkshire, and at a station in Glasgow, amount to 2 inches; at the top and bottom of the cathedral in that city, where it amounted to 0.1565 inch; and on Arthur's Seat, and the foot of that hill at Edinburgh, where it equalled 0.75 inch. Such was the origin of the barometer, which, in 1665, was used by Boyle in meteorological observations.

443. Since the period of the invention, barometers have undergone many improvements, and now they are constructed of various forms, but the principles of their action are the same. Otho Gürické the Burgomaster of Magdeburg—famous for his invention of the air-pump about the year 1654—had

[1] Pascal,—Grande Expérience sur la pésanteur de l'air.

[2] Power,—Exper. Philos.

[3] Sinclair,—Ars Nova et Magna Gravitatis et Levitatis; Schottus of Wirtemberg,—Technica Curiosa, 1664.

a water barometer erected in his house. In the University of Edinburgh, and in the Hall of the Royal Society of London, there are similar instruments. The inconvenient length of these huge barometers—nearly thirty-four feet—has led to the use of mercury in their construction.[1] The barometer, as usually made, is simply a tube about thirty-three inches long, filled with mercury, and inverted in a small cistern containing the same fluid, open to the influence ot atmospheric pressure. The mercury falls till its weight counterbalances that of the atmosphere upon the cistern, and oscillates in the tube according to changes in the density of the aërial fluid pressing on the cup. Barometers may be divided into three classes—the Study, Mountain, and Marine Barometers ; and these into several varieties. Figs. 1 and 2, which we owe to the kindness of Mr Dent, shew well the internal structure of the Marine Barometer. Fig. 1. represents it as generally met with ; Fig. 2. exhibits the mercurial tube detached. A B is the Torricellian tube dipping into the mercurial cup D ; E is an adjusting screw. The long *capillary* tube B gives the characteristic mark to this barometer : without it, the common instrument would be unfit for sea, for the motions of the ship would produce such agitation in the fluid as to render its indications uncertain, — with it, there is a sluggishness in the motion of the mercury which is an imperfection, but this is unavoidable. Two barometers for registering maxima

Mountain Barometer

Marine Barometer.

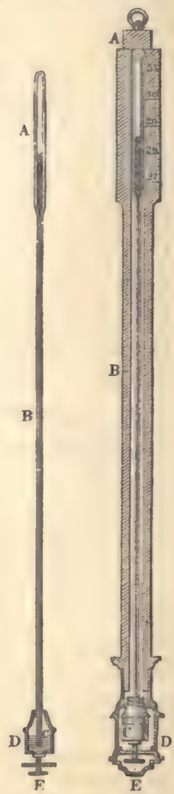
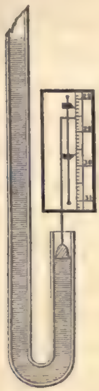


Fig. 2. Fig. 1.

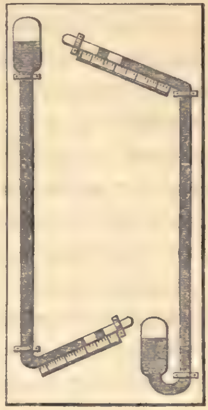
[1] Compar. between Water and Merc. Barom.,—Mem. Fr. Acad. i. 234.

and minima deserve particular notice: these are the instruments of Keith[1] and Traill.[2] On the continent, Fortin's, mo-

Keith's Barometer.



Traill's Barometer.



dified by Delcros,[3] is much esteemed, also Bunten's improved Gay-Lussac's barometer.[4] In this country the indications are read off in English inches and decimals; in France, in millimetres, 25.4 of which equal an English inch; in Germany, in French inches (marked with a double accent), and lines (marked with three accents), or more often in lines only, and decimals.

Aneroid Barometer.[5] Since writing the preceding paragraph, the author has inspected[6] this new and beautiful instrument, invented by M. Vidi. It was described by Professor Lloyd to the British Association,[7] and reported to have stood the test of being placed under the receiver of an air-pump, when the indications corresponded with those of the mercurial gauge to less than 0.01 inch. The principle upon

[1] Ed. Roy. Soc. Tr. v. iv.

[2] Encyc. Brit. 7th ed. vol. xvii. p. 530.

[3] Bulletin de la Soc. Géolog. de Fr. tom. xii. 1841.

[4] Arago,—Ferussac's Bul. des Sc. Math. x. 187; Gay-Lussac,—Annal. de Chimie et de Phys. i. 113.

[5] α privative, νηρος, and εἶδος—a form without moisture. See Dent on the Aneroid Barom.; Mech. Mag. No. 1307.

[6] At Mr Abraham's, Lord Street, Liverpool. The price is £3. It is $4\frac{3}{4}$ inches in diameter, and $1\frac{3}{4}$ inches thick. The scale is divided to 0.025 inch.

[7] At Swansea, in 1848.

which the instrument depends, is the pressure of the atmosphere upon a metallic chamber partially exhausted, and so constructed, that by a system of levers a motion is given to an index-hand which moves upon a dial.

The principle of the vacuum-case was formerly applied by M. Conté[1] in Egypt, but from the faulty mode of constructing his instrument, it was rejected and neglected.

Upon comparison of indications made with the Aneroid Barometer—not corrected for the particular temperature—and a very perfect mercurial barometer, given by Mr Dent, we find that from forty-nine observations made between the 6th January and 23d February 1848, the mean difference was 0.037 inch, the *aneroid* being in excess; and from sixty similar observations made with a standard barometer, during December 1848, and between the 3d and 31st January 1849, the mean difference amounted to 0.026 inch, the *mercurial* being, in this case, in excess over the aneroid barometer. Combining these observations (109 in number) a mean difference amounting to 0.0025 inch is found to exist, the indications of the aneroid being in excess.[2] For general use, the instrument is thus shewn to be well suited; for the measurement of heights it is peculiarly adapted, from its portability and comparative strength; and for nautical purposes we know of no better instrument.

Fig. 1. represents the external appearance of the Aneroid Barometer; Fig. 2. its internal arrangement, where the dial is supposed to be removed and the index-hand retained; and Fig. 3. a perspective view of the same.[3]

In Fig. 2. *a* is the metallic chamber or vacuum-vase, which receives the atmospheric impressions; it is corrugated in concentric circles, which increases its elasticity, and renders it more susceptible of atmospheric impressions; *b* is the tube, hermetically sealed, through which the air in *a* is exhausted.

[1] Bulletin des Sciences. Floreal, An. 6, p. 106.

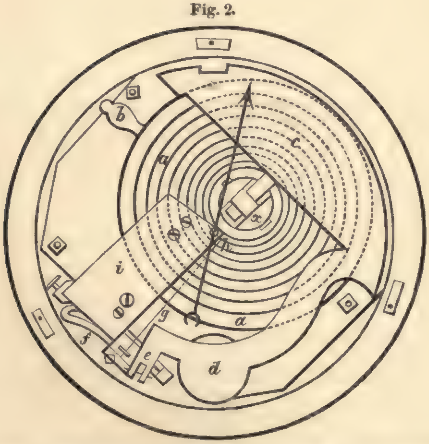
[2] The sum of all these observations gave 3239.712 inches for the aneroid, and 3239.44 inches for the mercurial barometer, the difference being 0.272 inch, which, divided by 109, = 0.00249.

[3] We beg to acknowledge the kindness of Mr Dent, in permitting casts to be taken of Figs. 3, 4, and 5,—Aneroid Barometer.

At the centre of a there is a solid cylindrical projection x, to the top of which the chief lever $c\ d\ e$ is attached—this lever, which is of the second order, rests upon two fixed pins, or

Fig. 1.

Fig. 2.



fulcra, placed vertically, and upon a spiral spring under d, but it is perfectly mobile. The extremity e of this lever is attached by a vertical rod and bow-shaped spring f, with another lever

to which a watch-chain *g* is fastened and extended to *h*, where it works upon a drum fixed to the axis of the index-hand, connected with a delicate spring at *h*,—the vertical motion is thus changed to a horizontal one, and the hand, which is attached to the metallic plate *i*, is thereby moved upon the dial. The movement originating in the vacuum-chamber is multiplied by these levers, so that a change in the corrugated surfaces, amounting to 1–220th of an inch, carries the point of the index-hand through a space of three inches on the dial.

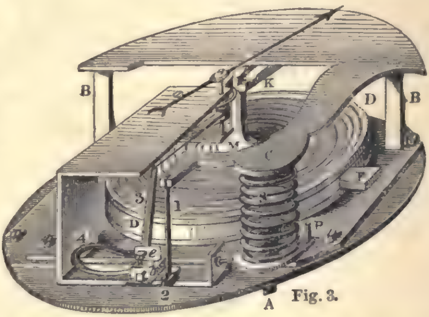


Fig. 3.

In Fig. 3. the vacuum-chamber is represented by D ; the large lever by C, resting upon the fulcra B B and spiral spring S, and supporting the box D by the pin K. At the extremity of C is seen the vertical rod (1) connecting it with the levers (2 and 3) by the bow-shaped spring (4). The square-headed screws *b e*, by screwing or unscrewing, admit an alteration in the distance of leverage, and thereby enable the index-hand to move over a space corresponding with the scale of a mercurial barometer. To the lever (3) is attached a light rod, terminating with the watch-chain, which is attached to the drum fastened to the axis. The handle is kept firmly fixed, when not in motion, by a delicate flat spiral spring attached to the axis, acting against the force of the levers, and always in a state of tension. F is the exhausting tube ; and A, at the back of the instrument, is a screw, which, upon being turned, alters the position of the index-hand, and thus enables the observer to adjust the aneroid to any mercurial barometer. The atmospheric pressure increasing on D, will cause a slight depression of the corrugated surface to which K is attached, and a corresponding inclination of the lever C ; but as this lever is resting upon unmoveable fulcra at BB, the motion will take place chiefly over the spiral spring S, the increased distance of the

lever being as six to one. The metallic chamber being 2.5 inches in diameter, the pressure of the atmosphere should be about 73 lbs. upon the corrugated diaphragms, but owing to various causes it is not more than 44 pounds.

Figs. 4. and 5. represent the vacuum-case, separated from the levers. The former shews the case before exhaustion;

Fig. 4.

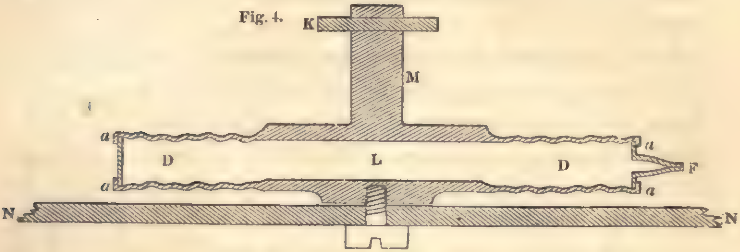
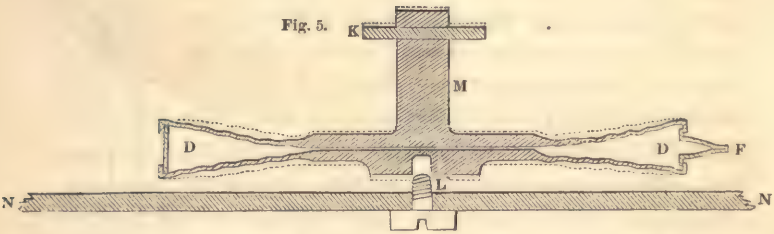


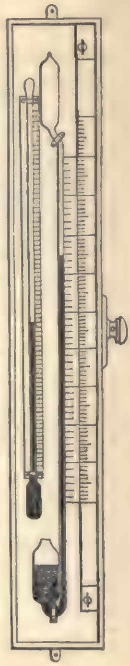
Fig. 5.



the latter after the air has been withdrawn. *a a a a* indicate the lapping over of the thin corrugated metallic diaphragms, where they are soldered to the rim; D is the vacuum-chamber, with F the exhausting tube; and L the screw part fixing D to the metallic plate N below. In Fig. 5, the vacuum-case is in a state of compression after being exhausted, and M represents the socket, which being pulled by the pin K, places D in a state of tension. The dotted line marks the position of the diaphragms after the introduction of the gas, which effects compensation for changes in the capacity of the case by alterations of temperature. Without this gas the capacity of the case would be diminished by heat, and increased by cold, but the changes in the elasticity of the gaseous fluid by varying temperatures, effect compensation.

In using the Aneroid barometer for scientific purposes, a

certain thermometrical correction is required. This is made by carefully noticing the indication of the instrument in the external atmosphere, then placing it before a fire till the thermometer indicates 100° F., and watching the change which has taken place. The variation of the hand, divided by the degrees of the thermometer, gives the quantity for each degree. The amount will be sometimes in excess, occasionally in defect.



444. *Sympiesometer.* From the barometer, the mind easily passes to the allied instrument of Adie, the Sympiesometer[1]—from συμπιεζω I compress, and μετρον a measure. The object of these instruments is similar; and from the peculiarities of the construction of the latter, it is exceedingly well adapted for being used at sea. The principle of its construction is the power of the atmosphere to compress a column of air, separated by a fluid which neither acts upon the confined gas, nor is acted upon by the external air. The instrument consists of a glass-tube about 18 inches long, and 0.7 inch internal diameter, having an oval bulb above, and terminating in an open cistern below. Into the tube and bulb, hydrogen gas is carefully introduced, and into the cistern, oil of almonds, coloured red by alkanet root. The atmosphere raises the unctuous fluid, and thus the gas is compressed according to the amount of external pressure. To provide against error from the changing bulk of gases under the influence of temperature, a thermometer and sliding scale are introduced, so that the instrument may be adjusted at the time of observation. The sympiesometer is exquisitely sensible to atmospheric mutations, even more readily so, than the delicate mercurial barometer, but it is inferior to it for meteorological purposes, chiefly in consequence of absorption of the hydrogen by the oil.[2]

[1] Ed. Phil. Jour. vol. i. p. 54.

[2] Edin. Encyc.—*art.* Meteorology, vol. xiv. p. 173; Forbes,—Edin. Jour. of Sc. x. 334; Ib. N. S. iv. 91, 329.

445. The *Thermometer*—(θερμὸς heat, and μέτρον a measure)—is the instrument used for measuring comparative temperature. Of heat we know nothing absolutely,—we speak of it relatively. The principle upon which changes in this instrument depend, is the facile transmission of caloric in different bodies, establishing equality of temperature between them, subject, however, to peculiarities in the conducting power of the respective media, and the expansion of the particles heated. The period of its invention was prior to the beginning of the seventeenth century, but the exact date and name of its original maker are uncertain.[1] In 1590, the physician Sanctorio[2] of Padua, constructed and used an air-thermometer. About the middle of the seventeenth century, this instrument was much improved by substituting spirit for the air. These thermometers were made by Italian artists, after a form sanctioned by the Academia del Cimento,[3] but they were clumsy and imperfect. The suggestion of mercury instead of spirit is said to have been made by Halley, but, according to Boerhaave,[4] it was Olaus Roemer—celebrated as the discoverer of the velocity of light by observations on Jupiter's satellites—who first constructed the mercurial thermometer. It was Fahrenheit[5] of Amsterdam, however, who completed this grand invention, and rendered it generally applicable. Most unfortunately, he was unhappy in the selection of his scale, but this arose from the imperfect knowledge of the times. So little was then known of the artificial means of abstracting caloric, in other words, of frigorific mixtures,[6] that, imagining the greatest cold could be produced by mingling salt and snow, he naturally made the temperature of that mixture the starting point, and denominated it zero. Observing that the freezing of water took place at a higher temperature, he divided the thermometric scale between these points into 32°, and fixed the boiling-point of the same fluid at 212°.[7] Soon the

[1] Vide Sig. Libri,—Annal. de Ch. tom. xlv. Dec. 1830; Martine,—Essays on Thermometers. [2] Commentaria in Avicennam.

[3] Saggi di Nat. Esperienze, i.——Count Lawrence Magalotti.

[4] Chemiæ Boerhaavii, i. 720. [5] Ph. Tr. 1724, vol. xxxiii.

[6] Sanctorio appears to ave had some knowledge of these mixtures,—Comment. on Avicenna, 1626.

[7] On the division of the scale, see Ann. of Philos. viii. 26, July 1816.

error which determined the zero-point was discovered;—greater cold than that, could be produced, and to meet the difficulty, instead of reforming the entire scale, a *minus zero* notation was adopted. This is to be deeply regretted, for the scale is neither philosophical, nor has it been followed throughout Europe, and a perplexing difference in the notation of various countries has been the consequence. Why should *we* retain a scale acknowledged to be imperfect? Let us relinquish all the rest, and adopt the *centigrade*. Were all the modern thermometers which have the scale of Fahrenheit, also marked with that of Celsius, the mind would be familiarized with both, and the former might gradually be withdrawn. The chief continental thermometers are those of Reaumur of France, Celsius of Sweden, and De Lisle of Russia. Reaumur,[1] divided the space between the freezing and boiling-points of water into 80 parts,—consequently 1° R. equals $2^\circ.25$ F., or they are as 4 to 9. In that of Celsius, the same space is divided into 100 degrees, hence termed the *centigrade thermometer*. This thermometer is very generally used by continental *savants*, and it is the one we should like to find introduced universally. The ratio of the degrees of Fahrenheit to Celsius is as 5 to 9, therefore $1^\circ \text{C.} = 1^\circ.8 \text{F.}$, and $1^\circ \text{F.} = 0^\circ.555 \text{C.}$ De Lisle used a descending scale, denominating the ebullition point of water zero, and the freezing-point 150 degrees.[2] The following formulæ will assist in reducing these scales respectively to the corresponding degrees of the others:—

$$\text{Fahrenheit}, = \frac{9\,\text{R.}}{4} + 32, \text{ or } 2.25\,\text{R.} + 32; = \frac{9\,\text{C.}}{5} + 32, \text{ or } 1.8\,\text{C.} + 32; = \left\{ (\text{De L.} - 150) \times 1.2 \right\} + 32.$$

$$\text{Reaumur}, \ldots\ldots = \frac{4\,\text{C.}}{5}, \text{ or } 0.8\,\text{C.}; = \frac{4\,(\text{F.} - 32)}{9}; = \frac{(\text{De L.} - 150) \times 1.2.}{2.25}$$

$$\text{Celsius}, \ldots\ldots = \frac{5\,\text{R.}}{4}, \text{ or } 1.25\,\text{R.}; = \frac{5\,(\text{F.} - 32)}{9}; = \frac{(\text{De L.} - 150) \times 1.2.}{1.8}$$

$$\text{De Lisle}, \ldots\ldots = \left\{ (\text{F.} - 32) \times 8.3 \right\} - 150.$$

In using these formulæ, regard must be had to the result, whether above or below zero, as an increment in the one case becomes a decrement in the other. This inconvenience may

[1] Vide Deluc,—Modifica. de l'Atmosph. i. 352.

[2] Thomson,—Outl. of Heat and Elect.

be remedied by using the following formulæ when the degrees of each scale are *below* zero :—

$$\text{Fahrenheit}, = \frac{9\,R.}{4} \backsim 32, \text{ or } 2.25\,R. \backsim 32; = \frac{9\,C.}{5} \backsim 32, \text{ or } 1.8\,C. \backsim 32.$$

$$\text{Reaumur}, \ldots\ldots = \frac{4\,C.}{5}, \text{ or } 0.8\,C.; = \frac{4\,(F. + 32).}{9}$$

$$\text{Celsius}, \ldots\ldots\ldots = \frac{5\,R.}{4}, \text{ or } 1.25\,R.; = \frac{5\,(F. + 32).}{9}$$

In consequence of the congelation-point of mercury being above some land temperatures, and considerably higher than many *artificial* colds, it is an unsuitable medium for universal application ; on the other hand, it is preferable to spirit for most scientific purposes,—consequently, in the polar regions, spirit-thermometers must be provided. Some have doubted the accuracy of the indications of these thermometers.[1]

To record *maxima* and *minima*, register-thermometers have been invented. Many years ago, Lord Charles Cavendish[2] constructed one for indicating the *maximum* temperature, but it is difficult to adjust. Others have been made by Six,[3] Keith,[4] and Traill ;[5] but that which is the best, especially for *minima*,

Six's Register Thermometer.

Traill's Register Thermometer.

is the thermometer of Rutherford.[6] As it is frequently met with, and is easy of adjustment, we will briefly describe it. It consists of two thermometers—one of them *mercurial*, the other *spirit*. In the former, *above* the mercury, there is a piece of steel, which is pushed on by that fluid, and retained in position by

[1] Dalton.—Syst. Chem. Philos.; De Luc,—Rech. sur les Mod. de l'Atmosph.; Ph. Tr. 1723, 1818; Ann. of Phil. xiii.; Forbes,—Ed. Encyc. xviii. p. 594, Ph. Tr. 1836, p. 577; Bellain,—Ann. de Ch. et de Phys. xxi. 330.

[2] Phil. Tr. 1757. [3] Ann. Phil. vii. 86; Phil. Trans. lxxii. 72.

[4] Ed. Phil. Tr. iv. [5] Encyc. Brit. xvii. 530. [6] Ed. Phil. Tr. iii.

the friction of the tube: it is adjusted by being brought down to the surface of the mercury by the attraction of a magnet. In the latter, there is an index of ivory or enamel, which sinks with the spirit as it retires in the tube of the instrument; but this index, in consequence of its shape, does not rise with the fluid upon an increase of temperature, for the spirit easily passes: it is adjusted by inverting and slightly shaking the thermometer, when the index runs along the tube till its summit is upon a level with the alcohol. The principle of this register-thermometer is simple, and were it not for its occasionally getting out of repair, it would be invaluable.

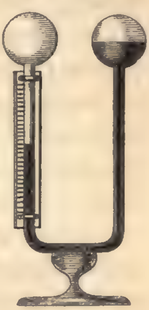
446. *Wollaston's Thermometer.*[1] In a former part of this treatise (vide 22), we have referred to an instrument for measuring altitudes by the ebullition-point of water, which was invented by the Rev. Francis John Hyde Wollaston, B. D., and described by him to the Royal Society, on the 6th of March 1817. This *thermometrical barometer*, the suggestion of which seems to have arisen in the Spanish philosopher Betancourt, consists of a thermometer of peculiar construction, a vessel for the reception of the water, and a lamp; the whole apparatus, when in use, being suspended on a tripod-stand, and protected by a curtain from the winds generally met with in elevated situations. The thermometer has a bulb one inch in diameter, with a dilatation in the stem immediately above; this portion of the instrument is enclosed in the metallic vessel. The tube of the thermometer is 1–40th of an inch in diameter, and the scale is so divided, that, with the assistance of a vernier, a thousandth part can be read off. The dilatation of the tube above the bulb, is intended for the reception of the mercury at temperatures between the freezing-point of water and the lowest temperature at which it is likely to boil, at altitudes in the country where the instrument is used. At the other end of the tube, a small cup is attached for receiving some of the mercury expelled, or for furnishing a portion to that already in the tube, if the height is such as to produce a great depression—thus the tube may be shortened without diminishing its delicacy, regard being paid to these alterations

[1] Phil. Trans. 1817, vol. lxxi. part ii. p. 184; Edin. Encyc. vol. xviii. p. 599; Encyc. Brit. xx. p. 575; Apjohn,—Annal. of Philos. vol. xviii. p. 292.

in the quantity of mercury while reading off the indication. The water-vessel is cylindrical, 5.5 inches deep and 1.2 in diameter, having double sides, for the purpose of preventing cooling, by the air confined in the interstitial space ; a steam-pipe is attached for carrying off the vapour during ebullition. When the apparatus is not in use, the thermometer with its scale may be separated from the boiler, inverted and screwed into it, while a cap secures the mercurial bulb from injury.

447. As we have referred to the *Differential Thermometer*, and will shortly mention its application, it may be well to describe this instrument briefly. Although it generally bears the name of "*Leslie's* Differential Thermometer,"[1] it was not the invention of that philosopher.[2] Sturmius[3] of Altdorff, seems to have been the first who constructed it, towards the close of the seventeenth century : it was *revived* by Sir John Leslie and Count Rumford, in the year 1804. This instrument consists of a glass-tube bent twice at right angles, so that the balls,—blown as nearly as possible of the same size,—at its extremities, are in a plane with the instrument and perpendicular to the stand upon which it rests. The tube and part of a ball are filled with a coloured fluid, and the rest contains air. It is termed *differential*, because its use is to distinguish between the temperatures of the balls : when *one* of these is affected by caloric, the expanded air depresses the fluid on that side and raises it on the other,—the comparison, therefore, is between the aërial fluids in the separate bulbs of the instrument.

Differential Thermometer.



448. *Anemometer*,[4] *Anemoscope*,[5] or *Vane*. The object of these instruments is in some respect similar: both indicate the *direction* of the wind, but the former, besides this, measures its intensity. The most ancient anemoscope or vane of which we have knowledge, is that which was placed upon the Temple of the Winds at Athens, erected by Andronicus Cyrrhastes.

[1] Exper. Inq. Nat. and Propag. of Heat.

[2] Colleg. Curios. p. 89, 90; Ed. Jour. of Sc. vol. ii. p. 144.

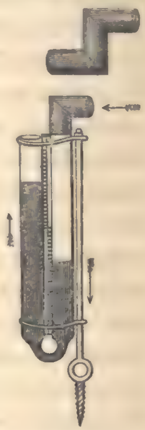
[3] Ib. p. 54, Nuremberg, 1676.

[4] ἄνεμος wind, and μετρον a measure.

[5] ἄνεμος, and σκοπέω I see.

The wind-card was then divided into eight different winds, which bore the following names,—naming them from N., by E.,—Boreas, Cæcias, Subsolanus, Eurus, Notus, Africus, Occidens, and Corus. The tower upon which stood the brazen triton with his pointing rod, was a marble octagon, built about a century and a half before the Christian era. It is described by Varro and Vitruvius, and stands to the present day—now a mosque occupied by the Dervises. The earliest *anemometer* of which we have a description is that of Croune;[1] since then, various instruments have been constructed by Hooke, Wolfius,[2] Martin,[3] D'ons-en-Bray,[4] Bouguer,[5] Smeaton,[6] Demenge,[7] the Marquis Polini,[8] Burton,[9] Pickering,[10] Lomonosow,[11] Pujoulx,[12] Dalberg,[13] Leslie,[14] Beaufoy,[15] and Brewster.[16] Professor Traill[17] describes two very simple instruments devised by him for registering *maxima* and *minima* veerings. The most convenient portable anemometer is that of Lind,[18] which depends upon the sustaining power of the wind over water, in a tube freely exposed to its influence. The instruments of Adie, and Whewell, improved by Robinson,[19] are good *stationary* instruments. Osler's[20] is a splendid observatory anemometer, too complicated to be well understood without diagrams, and when complete, expensive. Goddard[21] has contrived one, the indications of which are read off in the amount of fluid collected in vessels for that purpose, from an apparatus above, which liberates its contents, accord-

Lind's Portable Anemometer.



[1] Described in 1667 to the Roy. Soc.
[2] Op. Mathemat.
[3] Phil. Brit. ii.
[4] Mem. Acad. Par. 1734, i. 169.
[5] Tr. du Navire, de sa Constr. et ses Mouvemens.
[6] Exper. Inq.; Ph. Tr. 1759.
[7] Rozier's Obs. xv.
[8] De la Meilleure Maniere de Mesur. sur Mer le Chemin d'un Vaisseau.
[9] Philos. Brit. 2d vol. p. 211.
[10] Ph. Tr. vol. xliii.
[11] Comment. Novi Acad. Scient. Imper. Petropolitanæ, 1749, ii.
[12] Leçons de Phys. de l'Ecole Polytech.
[13] Rozier's Obser. 1781, t. xvii.
[14] Exper. Inq. on Heat.
[15] Ann. of Phil. xviii. 431.
[16] Edin. Encyc. *art.* Anemometer, vol. ii.
[17] Encyc. Brit. vol. xvii. p. 538; Ed. New Phil. Jour. 1837.
[18] Phil. Tr. 1775, v. lxv.; Hutton's Math. Dict.
[19] Brit. Assoc. 1846.
[20] Quart. Jour. of Met. No. 6; Illust. Polytech. Rev. Jan. 7. and Feb. 4. 1843.
[21] Athen. Sept. 21. 1844.

ing to the force of the wind, into the tube adjusted for the point of the compass from which the wind is blowing. Professor Phillips[1] has constructed another instrument, whose principle of action depends upon the intensity of cold produced by rapid evaporation resulting from the velocity of aërial pulses.

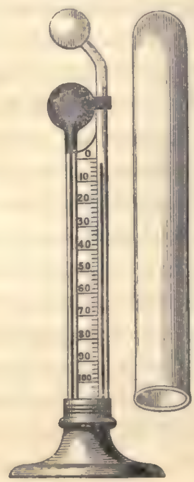
449. The *Hygrometer*,—ὑγρος humid, and μέτρον a measure. In the Philosophical Transactions for 1676, that which may be considered the first record of the hygrometer appeared,—it was the rude instrument of Coniers. Then, and for long after, the hygrometer was very imperfect, its changes depending upon the different weights of absorbent bodies when moist and dry. One of the best instruments of this kind has been invented by Dr Livingstone ;[2] it consists of a balance, with sulphuric acid in one of the scales. Upon a similar principle Professor de la Rive[3] constructed hygrometers in 1825. Our limits do not permit a description of all the hygrometers which have been contrived, we shall merely mention some, and state the principle of their action. This is either the expansion of the humid material and its subsequent contraction ; the indication of the dew-point ; or the rapidity of evaporation. From the context the rationale of these principles will be apparent. Let us premise the properties which Saussure[4] considered requisite in a perfect hygrometer. Such an instrument should shew very minute changes of humidity and dryness—the indications should immediately correspond with the atmospheric mutations—it should always record the same degree in the same hygrometric state of the air—it should be affected only by humidity and siccity, properly so called—and the variations in the scale should be proportional to those of the atmosphere. Wood,[5] ivory,[6] quills,[7] hair,[8] and whalebone[9] have been employed, likewise animal membranes,[10] whipcord and catgut ;[11] also the awn of the *Andropagon contortum*,[12] (Lin.), the *Oobeena Hooloo* of Mysore, that of the *Avena fatua*[13]

[1] Brit. Assoc. 1846. [2] Ed. Phil. Jour. vol. i. p. 116,—1819.
[3] Bib. Univ. Avr. 1825; Ed. Jour. of Sc. iii. 320.
[4] Essais sur l'Hygrométrie. [5] Conier,—Phil. Tr.
[6] Deluc,—Ph. Tr. 1773, p. 404; Leslie,—Ann. of Ph. i. 468. [7] Chiminello.
[8] Saussure; Biot,—Tr. de Phys. tom. ii. 199; Babinet,—Jour. de Pharmacie, Avr. 1824, Ed. Jour. of Sc. i. 309; Melloni,—Ann. de Ch. et de Phys. Jan. 1830.
[9] Deluc,—Ph. Tr. 1791. [10] Mr D. Wilson,—Ann. of Phil. ix. 319.
[11] Molyneux and Coventry. [12] Capt. Kater. [13] Hooke.

(Lin.), or wild oat, the *Funaria hygrometrica*, or common cord-moss, and the arista of the seed of the *Stipa pennata*[1] (Lin.), or common feather-grass ; Adie[2] has used the internal membrane of the *Arundo Phragmites* (Lin.), or common reed. The most elegant hygrometer is that of Daniell, constructed on the principles of evaporation. Pouillet,[3] Adie,[4] and Hayes,[5] have improved this instrument, but still it is objectionable, in consequence of the difficulty of observing the exact degree at which dew begins to be formed—in other words, the dew-point. A simple hygrometer is described by Jones,[6] Foggo,[7] and Coldstream,[8] consisting of a delicate thermometer, having its bulb of black glass, partially covered with muslin. Ether is applied to the muslin, and soon the uncovered portion of the bulb indicates the dew-point by the deposition of vapour

Daniell's Hygrometer.

Leslie's Hygrometer.



and depression of the mercury. About the close of the last century, Sir John Leslie[9] applied the differential thermometer

[1] Dr Cumming of Denbigh.
[2] Ed. Ph. Tr. vol. i. p. 32.
[3] Elem. de Phys. &c. ii. 732.
[4] Ed. Jour. of Sc. N. S. i. 60.
[5] Silliman's Jour. xvii. 351.
[6] Ph. Tr. 1826; Ed. Jour. of Sc. iv. 127.
[7] Ed. Jour. of Sc. vii. 41.
[8] Phil Tr.
[9] Encyc. Br. xiv. 731.

to the purposes of hygrometry. The idea seems to have been suggested by Hutton, to whom that distinguished Professor had the satisfaction of shewing the instrument, only a few months before the death of that great geologist. Hutton had himself constructed a hygrometer, on the principle of the variation of temperature indicated by a mercurial thermometer when moist and dry, but it does not seem to have been much known or esteemed. However, after the lapse of thirty years, M. August of Berlin,[1] has revived this instrument in Germany, under the name of the *Psychrometer*—(ψυχρὸς cold, and μέτρον a measure). It consists of two thermometers, one of which marks the temperature of the air, the other that at which evaporation from the moistened bulb takes place, and this indicates with considerable correctness the humidity of the atmosphere.[a]

450. The *Atmometer*, — ἄτμος moisture, and μέτρον a measure. The object of this instrument is to measure the exhalation of moisture from a humid body in a given time; it is useful besides, as an index of the velocity of wind, from acceleration of the dissipation of moisture under its agency. Leslie's atmometer consists primarily of a ball of porous earthenware, through which the contained water easily transudes. Arising from this is a tube of glass, having a scale attached, whose degrees correspond to the quantity of fluid which would cover to a determinate depth the external surface of the ball.[2] The amount of evaporation is read off in the descent of the fluid in the stem of the instrument, which must be freely suspended in the aerial current, and sheltered from rain and snow. Simple as this instrument is in the principle of its action, a serious objection against its continued

Fig. 1.—Leslie's Atmometer.
Fig. 2.—Anderson's Atmometer.

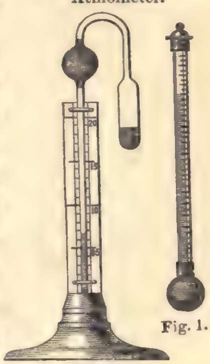


Fig. 1.

Fig. 2.

[1] Ueber die Anwendung des Psychrom. zur Hygrometrie; Ueber die Fortschritte der Hygr. in der neuesten Zeit. Berlin; Bulletin des Sc. Math. vii. 379; Compt. Rend. xiv. 63; Pouillet,—Elém. de Phys. ii. 570; Pog. Annalen, 1828.

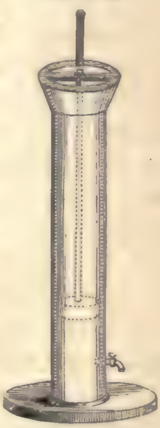
[2] Account of Exper. and Inst. depend. on relat. of air to heat and moisture.

[a] This is the *Dry and Wet Bulb Hygrometer* now so much in use.

use arises from frost, which closes up the pores of the ball. A very elegant atmometer has been devised by Dr Anderson.[1] It consists of a glass-tube of moderate calibre, bulging at the top, and curving from that enlargement, terminated in a bulb. This bulb is partially filled with alcohol, and the tube having been freed of air in the usual manner, is hermetically sealed. This instrument is fixed upon a stand, graduated to inches and decimals. To use this atmometer, wet the silk covering of the middle ball, sheltering the other ball of the instrument from rain. As the evaporation from this moistened ball lowers the temperature within, the alcoholic vapour rises from the bulb, and distils over, condensing in the expansion of the instrument, and collecting in the upright tube. The quantity of alcohol which comes over indicates the amount of evaporation. This is to be poured back, and a new series of observations begun.

451. The *Ombrometer*—ὄμβρος a shower, and μέτρον a measure—or rain-gauge, is an instrument of the most simple construction. It consists of a vessel shaped something like a funnel, whose dimensions bear a fixed proportion to each other. The superficies of the mouth-piece being accurately measured, and the scale of the instrument adjusted accordingly, the observer reads off in inches and decimals the quantity of rain which has fallen. Two important cautions are requisite,—to guard against error from evaporation after the fluid has entered the vessel, and to obtain a just estimate of the precipitation. To secure exactness, the instrument must be frequently consulted, and its position well chosen,—neither too high, nor too low, and if possible in an open exposure. The larger the superficies, the greater will be the accuracy of the observation.

Ombrometer or Rain Gauge.

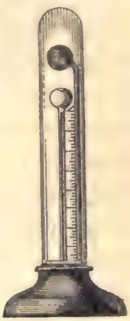


452. *The Photometer*—(φῶς light, and μέτρον a measure)—is an instrument, the intention of which is to ascertain the in-

[1] Ed. Phil. Jour. vol. ii. p. 64; Edin. Encyc. *art.* Meteorology.

tensity of light. The late Sir John Leslie[1] applied for this purpose a peculiar form of the differential thermometer, the indications of which depend upon the fact, that as caloric accompanies solar light, the amount of the one becomes an index to the intensity of the other. One of the balls of this thermometer is blackened, while the other remains diaphanous ; a glass-case encloses the instrument and defends it from atmospheric influence. As the light darts upon this photometer, the darkened ball retains the heat, and the contained air being thereby expanded, the fluid rises in the opposite stem, to a height proportionate to the calorific impression. The indications of this instrument, as in the case of the thermometer, are only relative. Count Rumford[2] invented a photometer depending upon the depth of shadow produced.

Leslie's Photometer.



Lampadius[3] and Horner[4] have constructed photometers on the principle of the obstruction of opaque bodies to the transmission of light, but there are practical objections to these instruments, apart from the error which may result from polarization of the ray. Some years ago a photometer was made by Mr A. Ritchie,[5] upon the principle that radiant heat is conducted through thick plates of glass in the same manner as through opaque substances—that light expands those bodies which absorb it—and that the intensity of light is inversely as the square of the distance. The delicacy of this instrument was shewn by its sensibility to a candle placed twenty-five feet off, while no effect was produced by a hot ball of iron radiating greater heat ; lights at different distances gave expression to their intensity in accordance with the laws stated.

453. *The Cyanometer*—(κύανος blue, and μέτρον a measure)—is an instrument invented by M. de Saussure.[6] It is a cir-

[1] Expr. and Inst. depend. &c.
[2] Phil. Trans. 84; Essays.
[3] Ann. of Philos. vii. 3.
[4] Bibl. Univ. vi. 162.
[5] Roy. Soc. Dec. 16. 1824; Ed. Jour. of Sc. ii. 321.
[6] Mém. de Turin, 1788, 1789; Jour. de Phys. 1791, tom. i.; Voy. dans les Alpes, 2009.

cular card about four inches diameter, a ring of which at the circumference is divided into fifty-three equal compartments, each coloured with a shade of blue, varying in depth from the palest sapphire to the deepest indigo. The first is so pale that it looks white at the distance where a black spot 1.75 lines broad is invisible ; the next is darker than the first only as much as to appear of a similar shade with it, when removed as far off as the first was from the black spot. Following this law throughout, the last cannot be distinguished from black at a similar distance. Thus constructed, the cyanometer is seriously objectionable, for neither are the tints permanent, under hygrometric changes and the influence of light, but two instruments can scarcely be constructed in every shade alike. A suggestion of Dr Traill is worthy of particular attention, that the cyanometer should be constructed of blue glass, thin films of which being superimposed would produce the required hues, the whole to be enclosed between plates of crown glass.

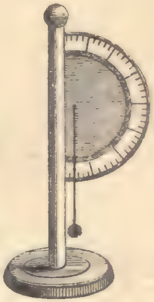
454. *The Electrometer.* This instrument has passed through many changes and improvements, according to the purpose of the inventor. The object is the same in all, though some only are useful in meteorology. The principle of their construction depends upon the repulsion of bodies similarly electrified. The electrometer of Saussure consists of a glass vessel in which two pith-balls are delicately suspended by fine silver wires. These diverge towards pieces of tin-foil fastened upon the inner surface of the apparatus. A better instrument is that of Bennet,[1] which consists of a glass cylinder with a metallic cap, in the centre of which a wooden wedge is inserted. On either side of this, a strip of gold leaf, about two inches long and quarter of an inch broad, is attached, and opposite to each, tin-foil is pasted within the glass, rising a little above the lower edge of the gold leaf, and connected below with the brass stand of the instrument. For convenience of use, a pointed wire rests upon the cap with which the gold leaf is in apposition. An electrometer more delicate

[1] Phil. Trans. lxxvii. 26.

than either of these, is the Torsion Balance of Coulomb,[1] one degree of which equals a force of not more than the 100,000th

Gold-leaf Electrometer.

Quadrant Electrometer.



part of an English grain,—so exquisitely sensible is this instrument of electrical impressions. Henley's[2] Quadrant electrometer is useful for general purposes: it is made with a semicircle of ivory fixed upon a rod rising from a stand, from the centre of which a pith-ball is hung by a piece of slender cane; the elevation of this ball indicates the amount of electric tension.

Such are the chief instruments used by the meteorologist; but in addition to these,—for the due observance of the magnetic effects of the aurora borealis, and terrestrial magnetism,—his observatory should be furnished with those constructed for indicating magnetic impressions. Neither should there be omitted, photographic papers for tabulating the chemical force of the solar beams, a *polariscope*, nor an instrument for measuring radiation, such as the delicate *actinometer* of Herschel.

[1] Mém. Acad. Paris, 1785. [2] Phil. Trans. lxii. 359.

The symbol % is used throughout to indicate *per cent.*

The French *Millimetre* (*mm*) equals 0.03937 English inch. 762 *mm* = 30 Eng. in., or more correctly 29.9999.

The *Metre* (*m*) equals 39.37100 Eng. in., or 3.28089 feet.

The *Toise* equals 1.949036 metres, or 6.39495 Eng. feet.

The old *Paris Foot* equals 1.06578 foot Eng.

The *Gramme* equals 15.438 gr. troy.

To convert *centigrade degrees* into those of *Fahrenheit*, by mental calculation, double the former, and deduct one-tenth of the product, add 32° if the temperature is above the freezing-point, but if below it subtract the product from 32°.

MICROSCOPIC REPRESENTATIONS OF RED SNOW.

(Vide p. 199, § 215.)

Fig. I.

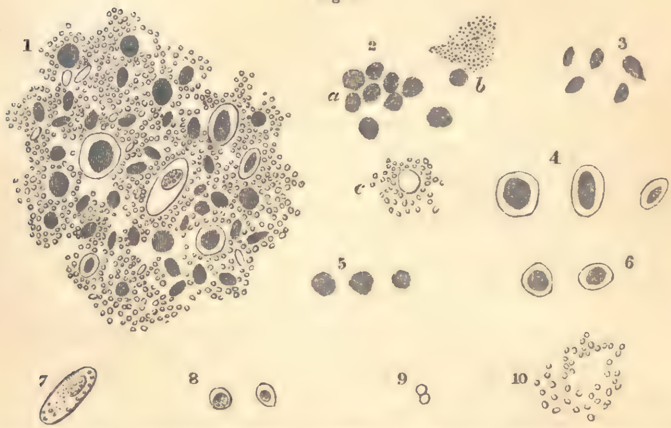


Fig. I. represents Red Snow of the Grimsel, magnified 300 times: Shuttleworth,—Jameson's Journal, No. 57, coloured plate.

1. Represents the general appearance of the snow, the dark patches being coloured red.
2. *a*, globules of *Protococcus nivalis;* *b*, a globule whence sporules have escaped; *c*, a globule surrounded with the *Protococcus nebulosus* (10),—Kutzing.
3. *Astasia nivalis*,- Shuttleworth.
4. *Gyges sanguineus*,—Shuttleworth.
5. and 6. Other infusoria (coloured red).
7. and 8. Other infusoria uncoloured.
9. *Monas gliscens.*
10. *Protococcus nebulosus*,—Kutzing.

Fig. II.

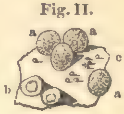


Fig. II. represents the Red Snow as given by Carpenter,—Princip. of Gen. and Compar. Physiol. 2d ed. p. 76.

Protococcus nivalis,—a, a, a, vesicles or cells containing germs; b, the same ruptured; c, the liberated germs becoming developed.

DIAGRAMS AND ENGRAVINGS.

INDEX.

I. INDEX OF SUBJECTS.

II. INDEX OF NAMES.

ERRATA.

Page 3, line 17, *for* atonic *read* atomic.

N. B.—This expression is employed in reference to the quantitative constancy of the elements, oxygen and nitrogen. The atmosphere is not a chemical combination, but merely a mechanical blending of its ingredients.

Page 4, last line in notes, *for* No. 5, *read* xxii. 75.
— 5, lines 7 and 5 from bottom in note, *delete* " carbonate of," *and* " with the carbonic acid of the lime."
— 7, line 26, *for* Germany *read* Sweden.
— 8, — 12 from bottom in note, *read* 200 oz. by measure.
— 45, — 5 from bottom, *for* 90°, *read* 9°.
— 214, foot-notes, *transpose* the figures 1 and 2.
— 228, line 7, *for* second *read* third.
— 244, 272, *for* Lattire *read* De la Hire.
— 312, note 1, *for* Benedictus *read* Benedicti Monachi.

EDINBURGH: PRINTED BY JOHN GREIG.

The Course of Time. A Poem in Ten Books. By ROBERT POLLOK, M.A. A New Edition, (being the Nineteenth,) with Portrait, engraved by Robinson. In small 8vo, 7s. 6d., neatly bound in cloth.

Poems by the Lady Flora Hastings. With a Portrait. Second Edition, foolscap 8vo, price 7s. 6d.

Solitary Hours. By Mrs Southey. In foolscap 8vo. A New Edition. Price 5s.

The Birthday and other Poems. By the same Author. In foolscap 8vo, price 7s.

Robin Hood: a Fragment. By the Late Robert SOUTHEY, and CAROLINE SOUTHEY. With other Fragments and Poems by R.S. and C.S. Crown 8vo, price 8s.

Chapters on Churchyards. By the same Author. Second Edition, foolscap 8vo, price 7s. 6d.

Domestic Verses. By Delta. In one Volume, foolscap 8vo, price 5s. bound in cloth.

The Poetical Works of Thomas Aird. In 8vo. Price 5s. cloth.

The Poems and Ballads of Schiller. Translated by SIR EDWARD BULWER LYTTON, BART. With a brief Sketch of Schiller's Life. In Two Volumes crown 8vo, price One Guinea.

Now and Then. By Samuel Warren, Esq. F.R.S. Author of "Ten Thousand a-Year," and the "Diary of a Late Physician." A New Edition, (the third,) with the Author's last corrections, and a Preface, elegantly bound in cloth gilt. Price One Guinea.

The Diary of a Late Physician. By the same Author. A New Edition. Complete in Two Volumes. Price 12s.

Ten Thousand a-Year. By the same Author. A New Edition. Three Volumes. Price 18s.

The Moral, Social, and Professional Duties of ATTORNEYS AND SOLICITORS. By the same Author. Foolscap 8vo. Price 9s.

The Baronial and Ecclesiastical Antiquities of

SCOTLAND. Illustrated by R. W. BILLINGS and W. BURN, Architects. To be completed in Sixty Monthly Parts, each containing Four Large Engravings on Steel by J. H. LE KEUX and other Artists, and one or more Woodcuts, with Descriptive Letterpress. Price, in medium 4to, 2s. 6d. each. Vols. I. and II., comprising Parts I to XXX., may be had in cloth ; price, in medium 4to, £2 each.

The Infinity of Geometric Design. Exemplified

by Forty Plates, comprising upwards of Two Hundred Illustrations, in proof of the systematic Composition of Tracery. By ROBERT WILLIAM BILLINGS, Architect, Author of various Architectural publications. Medium 4to, price 25s.

Ancient and Modern Art, Historical and Critical.

By GEORGE CLEGHORN, Esq. of Weens. Second Edition, corrected and enlarged. In Two Volumes, foolscap 8vo, price 12s.

Lectures on the History of Literature, Ancient and

MODERN. From the German of FREDERICK SCHLEGEL. A New Edition. In One Vol. foolscap 8vo, price 5s.

The Recreations of Christopher North. In Three

Volumes, Post 8vo, price £1, 11s. 6d.

The Angler's Companion to the Rivers and Lochs

OF SCOTLAND. By THOMAS TOD STODDART. To which is added, a Description of the Angling Stations where Sport and Accommodation are to be met with, accompanied with a Map of Scotland, constructed for this work, and other Illustrations. In post 8vo. Price 10s. 6d.

Lays of the Deer-Forest. A Selection from the

Original Poems of JOHN SOBIESKI STUART and CHARLES EDWARD STUART. With an Essay on Deer-Stalking and Roe-hunting, Notes of Remarkable Incidents in Forest Sports, Traditions of the Clans, and Notices of Natural History in the Deer-Forests. In Two Volumes, Post Octavo, price 21s.

Hudson's Bay ; or, Every-Day Life Scenes in the

WILDS OF NORTH AMERICA. By ROBERT M. BALLANTYNE. Crown 8vo, with Illustrations, price 9s.